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VARIATIONS IN CODLING MOTH INJURY IN NORTHWESTERN ARKANSAS[1]

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The codling moth problem in northwestern Arkansas has appeared to increase in difficulty, somewhat irregularly, for a period of years, reaching a peak in 1932 and 1933. The increasing difficulty of this problem, judging by recent entomological literature, has not been confined to Arkansas. The opinion that the codling moth is becoming resistant to arsenicals in use has been expressed frequently by growers and at least partially accepted by entomologists. The positiveness of this view was lessened in 1934, when fairly good commercial control was secured, and still further in 1935 when the infestation was as easily controlled as it had been in 1919.

The recurrence of a light infestation has reopened the question of resistance, and of the relation of environmental factors to codling moth abundance. The writers have records of injury by the codling moth in northwestern Arkansas from 1918 to 1935 inclusive, and spraying experiments for 11 of these 17 years.[2] These records are not of equal value for the various years since during a part of this period other problems took precedence over codling moth investigations. While not as complete as desired, a review of the codling moth infestations of this period should be useful and is presented here in summary.

The period of the observations under discussion began with two contrasting seasons. The first, 1918, was for some years regarded as the high mark of codling moth injury. In many of the better kept orchards the infested fruit approached or exceeded 50 per cent of the total crop. The succeeding year, 1919, was characterized by a very light infestation and

[1] Research paper No. 417, Journal Series, University of Arkansas.
[2] The senior author has been connected with codling moth work in northwestern Arkansas, first with the Bureau of Entomology and later with the Arkansas experiment station, since August 1917. The junior author became connected with codling moth investigations in Arkansas in 1927.

in most of the well-cared-for orchards codling moth injury was negligible. Following that season the senior author participated in an optimistic report on the codling moth problem in the Ozarks (*2*). The infestation in 1920 was again very heavy and the losses were similar to, if not quite as severe, as those of 1918. In 1921 a killing frost destroyed the commercial apple crop with the result that the infestation in 1922 was light, and in many orchards negligible. These two years represent the same sequence of conditions as in 1908 and 1909, reported by Jenne. The crop in northwestern Arkansas was largely destroyed by frost in 1908. The following year only 33.26 per cent of fruit on the unsprayed check was wormy (*3*, *4*).

During 1923 and 1924 the codling moth was held in control so well that the problem was considered closed and no experiments were carried on in northwestern Arkansas in 1925. This is unfortunate for it would be instructive to compare records in experimental plots of 1925 with those of 1932 and 1933. At any rate, in 1925 a new record for injury was set and the crops in many orchards were almost totally infested. Following this season assertions were frequently made that poisons were no longer effective in codling moth control and that the pest was changing its habits. The codling moth was readily controlled again in 1926, although the problem was more difficult than it had been in the years between 1920 and 1925. In 1927 the apple crop was "spotted" because of a scattered frost and where the crop was light the infestation was often heavy. During 1928 the infestation was similar to 1923 and 1924.

Table 1.—Percentage of infested fruit from comparable sprayed plots and uninfested checks in northwestern Arkansas from 1918 to 1935.*

Year	Percentage of Infested Fruit	
	Typical sprayed plot	Unsprayed check
1918	14.44	72.66
1919	.72	47.54
1920	16.08	92.96
1922	.84	13.53
1923	8.48	77.61
1924	7.45	75.4
1926	9.76	89.13
1928	13.04	90.35
1933	33.55	unchecked
1934	21.02	75.97
1935	.95	56.7

* The records in this table for 1918 to 1924 are copied from Ark. Ext. Cir. 215 (*1*), and represent experimental work carried on by the Bureau of Entomology.

During the five-year period from 1929 to 1933 inclusive, the problem appeared to increase in difficulty and in the last two years injury was coming to be regarded as uncontrollable. In 1934 the first brood worms were as abundant as they had been in 1933, but during the excessive heat of July and August, reproduction nearly stopped and infestation almost faded out. As a result a large proportion of the harvested fruit was free from injury. The infestation in 1935 was about as light as in 1919. Even in some orchards where no summer applications were made there was relatively little worm injury.

Definite data in support of the field observations are supplied by records of infestation in plots on which spraying experiments were conducted. Some records have been published previously (*1*, *2*). The percentages of infested fruit for the sprayed plot which most nearly represented the same conditions over the entire period and an unsprayed

check are given in table 1. The insecticide used on the sprayed plot was arsenate of lead, usually applied with a fungicide. The dosages and schedules followed for the different years were not uniform, but for the plots in this table they were those recommended for the years in question. The method in making applications on these plots was the same and the variety was Ben Davis in all years except 1928. All records represent counts of all fruit dropped and harvested from at least five trees per plot. Plots in which an accessory material like summer oil was used with arsenate of lead, and which particularly in 1933–34 gave better results than where the arsenical was used alone, are not included.

Nevertheless, conditions in the experimental plots are not comparable in all respects since the spraying schedule was increased until it called for two more applications after 1932 than it had in 1918. The work during the different years was not in the same orchard and while heavily infested orchards were always chosen, they did not all represent the conditions of the belt equally well.

From table 1 it is obvious that 1919, 1922 and 1935 were the years of light infestation. This agrees with the field records. The small infestation in 1922, however, was not a response to conditions of that year, but to the almost complete failure of the apple crop the previous year. The records for 1928 appear worse than those for 1923 and 1924, although from field observations these years should be grouped together. On the other hand the orchard in which the experiments were conducted in 1926 presented an easier problem than those used during the previous years. The years 1918 and 1920 are readily classed together. It is difficult to compare 1934 with any other year, since the early infestation was very heavy while the injury on harvested fruit was less than that of 1918 and 1920. Even on the unsprayed check the injury to harvested fruit was only 54 per cent. Obviously the worst year was 1933.

The severity of infestation may be grouped by years as follows: Years of very light infestation, when even poorly sprayed orchards were relatively free from worms—1919, 1922 and 1935. Light infestation when 80 to 90 per cent or more of the fruit was free from worms in well-sprayed orchards—1923, 1924 and 1928. Medium infestation, during which severe losses frequently occurred—1926, 1927, 1929, 1930, 1931 and 1934. Possibly 1926 belongs with this last group, and 1930 and 1931 with the following one. Heavy infestation during which losses in well-cared-for orchards frequently approached 20 to 40 per cent—1918, 1920. Most severe injury—1925, 1932 and 1933.

Among the factors which have been responsible for this variation in abundance of the codling moth, the climatic conditions at the time of flight of moths of the overwintered brood appear to be most important. During the severe years, 1918, 1925, 1932 and 1933, the temperature during May and June was distinctly above normal. During the light years, 1919, 1923, 1924, 1928 and 1935, the temperature during this same period was below the mean. Similarly during years of heavy injury the rainfall was below the mean during the period of flight of moths of the overwintered brood, while during the light years for the same period it was above normal.

It is difficult to find any consistent relationship between the summer weather and codling moth abundance. The mean temperature for July and August during the years of heaviest injury is higher than for those of light injury and in general it may be said that high summer temperatures favor reproductivity of the codling moth. Nevertheless, summer temperatures are always high enough to be within the range of favorable temperature for development and reproduction.

Probably the temperature hazard to the codling moth in summer is more likely to be from temperatures that are excessively high rather than from those that are low. The only obvious instance of temperature being so high as to inhibit the development of codling moth for any extended period was in 1934, when the average temperature for July and August was 84.85° F, or 6.8° F above the all-time mean. Temperatures for the same months in 1935, the next hottest July and August, were 3.5° above the normal mean. Continuance of warm weather into September and early October doubtless extends the breeding season.

There are other factors besides acquired resistance and temperature which may have brought about a change in the codling moth problem. A large percentage of the acreage which was in the moderately susceptible variety Ben Davis and the less susceptible Winesap has been changed since 1918 to the very susceptible varieties Delicious, Staymen, and Golden Delicious. Spraying equipment and methods have changed in favor of more power and more speed. The financial condition of the fruit grower tends to stress economy more than appeared to be necessary in 1919. Tolerances on insecticides on fruit have been established in the later part of the period.

The data presented indicate the variability of the codling moth problem. They also show the impossibility of drawing final conclusions, either regarding control or habits from the observations or experiments of a single year, or even for a period of four or five years.

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(*1*) **Ackerman, A. J.** and Dwight Isely. 1926. The control of unusually severe outbreaks of the codling moth. Ark. Ext. Circ. **215**. 4 pp.

(*2*) **Isely, Dwight** and A. J. Ackerman. 1920. Some features of the codling moth problem in the Ozarks. Jour. Econ. Ent. **13**(1):159–66. Feb.

(*3*) **Jenne, E. L.** 1909. The codling moth in the Ozarks. U.S.D.A., Bur. Ent. Bul. **80**(1):1–32. 8 figs. June 26.

(*4*) **Quaintance, A. L.,** E. L. Jenne, E. W. Scott and R. W. Brancher. 1911. The one-spray method in the control of the codling moth and the plum curculio. U.S.D.A., Bur. Ent. Bul. **80**(7):113–46. 2 pls. (4 figs.). March 30.

Early in March, Dr. C. O. Eddy, formerly associate entomologist of the Kentucky Agricultural Experiment Station, joined the staff of the Louisiana Agricultural Experiment Station as head of the Department of Entomology.

Dr. Paul O. Ritcher of the University of Wisconsin, Department of Economic Entomology, and agent of the federal Bureau of Entomology, has resigned to become assistant entomologist of the Kentucky Agricultural Experiment Station.

Dr. E. B. Breakey, recently employed on a Crop Production Institute project in the Department of Zoology and Entomology of the Ohio State University, has been appointed entomologist at the Mellon Institute, Pittsburgh.

EFFECT OF ORCHARD PRACTICES ON CODLING MOTH AND LEAFHOPPER PARASITISM[1]

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Most investigators working on problems of orchard insect control will agree that certain orchard practices, particularly spraying and dusting, probably interfere with and cut down the effectiveness of a number of beneficial parasites and predators. Little data have been published to show the extent to which these practices interfere with beneficial insects. Driggers[2] showed that in dusting peaches with talc to control the Oriental fruit moth the fine talc dust on the foliage practically eliminated the work of *Trichogramma* sp., which, at the time of dusting in the particular orchard under observation, was destroying 50 per cent or more of the Oriental fruit moth eggs. Recently Cox[3] presented data which showed that codling moth parasitism by *Ascogaster carpocapsae* Vier. was considerably lower in sprayed than in unsprayed orchards and that the arsenate of lead used in the sprays was poisoning the adult parasites. Pepper & Driggers[4] have reported observations and data which indicate that larval parasitism of the Oriental fruit moth was higher in peach orchards with a moderate weed growth than in orchards that were clean cultivated. Evidence was submitted to show that the weeds harbored insects capable of serving as alternate hosts for certain of the Oriental fruit moth parasites and thus served to carry over the winter a larger number of beneficial insects.

The work referred to concerning fruit moth parasitism led the writers to undertake further studies in apple orchards in 1932 to determine the effect of different spray treatments on codling moth and leafhopper parasitism. Some data were obtained also on the relative degree of codling moth parasitism in a heavily sprayed and clean-cultivated orchard compared to a heavily sprayed and weedy orchard. Studies were also made in an unsprayed and weedy orchard for comparison with the heavily sprayed orchards. The work was hastily planned and carried out as time could be spared from other duties, hence is open to criticism from several angles. The results of the studies are presented as preliminary data with the idea that at some future date the writers or others will have an opportunity to continue the study.

Codling moth egg parasitism in sprayed and unsprayed orchards.—During the late summer of 1932 the writers studied the effect on codling moth egg parasitism of heavy spraying in the two-brooded codling moth area at Glassboro, N. J. The sprayed orchard received nine codling moth cover sprays of lead arsenate and lime, with summer oil emulsion at the peak of broods, at approximately 10-day intervals from the first of June to the middle of August. An orchard nearby which received no

[1] Paper of the Journal series, New Jersey Agricultural Experiment Station, Department of Entomology.
[2] JOUR. ECON. ENT. **23**(1):209–15. Feb. 1930.
[3] JOUR. ECON. ENT. **24**(1):200–4. Feb. 1931.
[4] Ann. Ent. Soc. Am. **27**(4):593. Dec. 1934.

sprays in 1932 was selected to serve as a check. Codling moth eggs approximately 12 hours old were obtained by placing peach and apple twigs in breeding cages in the insectary. A number of twigs were secured and placed, one twig to a tree, in a row running across each orchard. Two lots of twigs bearing eggs were placed in each orchard on August 22 and 25. At the end of three days the twigs were collected and returned to the insectary for observation. The data from this experiment, set forth in table 1, show that 5 per cent or less of the eggs were destroyed by *Trichogramma* sp. in the sprayed orchard, compared to 55 and 64.5 per cent of the eggs so parasitized in the two lots in the check orchard. The study was carried no further than the egg stage, therefore the parasitism by *Ascogaster carpocapsae* Vier. was not determined.

Larval and pupal parasitism in three orchards.—About the middle of August 1932, the writers collected codling moth cocoons in three orchards in the Glassboro district to determine the relative larval and pupal parasitism. The first orchard was one heavily sprayed and clean cultivated to a point where very few weeds or grass were present. The

Table 1.—Per cent of codling moth eggs destroyed by *Trichogramma* sp. in a heavily sprayed and an unsprayed orchard at Glassboro, N. J., in 1932.

Orchard Number	Treatment	Date Eggs Were in Orchard	Total Employed		% Parasitized	
			Twigs	Eggs	Twigs	Eggs
1	Heavily sprayed	Aug. 22–25	43	529	11.6	5.1
1	Heavily sprayed	Aug. 25–28	30	342	10	2.6
2	Unsprayed	Aug. 22–25	37	358	62.1	55.3
2	Unsprayed	Aug. 25–28	35	288	62.8	64.5

second orchard was sprayed as heavily as the first orchard but was cultivated in such a manner that roughly half of the orchard was growing weeds and grass. The third orchard was neither sprayed nor cultivated during 1932 and had an abundance of weed growth. The last two orchards were the same two orchards in which the egg "planting" experiments were carried out, the results of which are recorded in table 1. Table 2, which sets forth the number of larvae and pupae collected and the percentage of parasitism as determined from rearing the material, shows that both larval and pupal parasitism was higher in the well-sprayed and weedy orchard than in the well-sprayed and clean-cultivated orchard. The unsprayed orchard showed 71 per cent of the larvae parasitized, which was roughly four and one-half times the larval parasitism found in the well-sprayed but weedy orchard. The pupal parasitism, on the other hand, was only 9 per cent, which was approximately half the pupal parasitism in the heavily sprayed and weedy orchard.

Leafhopper parasitism under different spray treatments.—During the late summer of 1932 an opportunity was afforded to study the relative leafhopper abundance and parasitism in three sections of an orchard treated differently in regard to spray applications. The different sections of the orchard were treated as follows: Approximately one-third of the orchard was unsprayed following the calyx application except for a few trees scattered here and there that had set a crop of fruit. The remaining two-thirds (consisting of approximately 420 trees equally

divided between the varieties Rome Beauty, Wealthy and Stayman Winesap) was sprayed four times during May and June with lead arsenate and lime, except in one spray at the peak of first-brood egg deposition, when lead arsenate and summer oil emulsion was used. The block of 420 trees was divided into three plots at the beginning of second brood. Plot 1, consisting of approximately 130 trees, was sprayed four times in July and August with lead arsenate and lime, except that the second and third application carried oil with the lead arsenate. Plot 2, consisting of 190 trees, was sprayed four times in July and August with nicotine tannate. Plot 3, consisting of approximately 95 trees, was sprayed the same as plot 1. The set-up described gave a large block of trees unsprayed for the most part after the calyx application, two fairly large blocks sprayed with lead arsenate or lead arsenate and oil in first and second brood, and a large block between the two lead arsenate blocks for which the first brood was sprayed with lead arsenate and the second brood with nicotine tannate.

Table 2.—Codling moth larval and pupal parasitism found in three orchards at Glassboro in mid-August 1932.

Orchard Number	Treatment	No. Collected		No. Parasites		% Parasitism	
		Larvae	Pupae	Larval	Pupal	Larval	Pupal
1	Heavily sprayed, clean cultivated	53	61	4	0	7.5	0
2	Heavily sprayed but weedy	60	39	10	7	16.6	18
3	Unsprayed and weedy	107	90	76	7	71	9.2

About the middle of August it was observed that leafhoppers, mostly *Empoasco mali* LeB., were much more numerous on the lead arsenate-sprayed blocks than on the nicotine tannate blocks. This difference in leafhopper abundance between lead arsenate-sprayed plots and nicotine tannate-sprayed plots had been observed previously by Headlee, Ginsburg & Filmer[5] but they had advanced no explanation for the observations. It was further observed by the writers that, whereas the nicotine tannate-sprayed block had less leafhoppers than the lead arsenate-sprayed blocks, the block which had received no spray since the calyx application had less leafhoppers present than the nicotine tannate-sprayed block. This suggested the possibility that the observed difference in population might be due to a difference in degree of leafhopper parasitism brought about by the different treatments.

The junior writer determined the relative leafhopper population in the different blocks by sweeping with a hand net for 30 minutes in each plot on September 10. Five sweepings were made from the side of a tree, bringing the net in contact with the ends of the apple twigs at each sweeping. The hoppers were then transferred from the net to a suitable container with the aid of a collecting device similar to the one described by Poos[6] and the sweepings resumed. Since many more hoppers were collected with a given sweep of the net in the lead arsenate plots and

[5] Jour. Econ. Ent. 23(1):45. Feb. 1930.
[6] Jour. Econ. Ent. 22(1):146. Feb. 1929.

since an appreciable amount of the thirty-minute period of time was consumed removing the hoppers from the net, it follows that a larger number of sweepings were made in the check plot and the nicotine tannate-sprayed plot than were made in the lead arsenate-sprayed plot.

After the hoppers were collected and killed it was observed that many of them, particularly those from the unsprayed blocks, were parasitized by a hymenopterous parasite belonging to the genus *Aphelopus*. These parasites, which have been studied and described by Fenton,[7] were easily detected under the wings of the hoppers. The junior writer examined between 500 and 700 hoppers from each of the three plots to determine the percentage of parasitism by *Aphelopus* sp. No further tests or examinations were made to determine if other parasites were playing a part in the reduction of the hopper population in the different blocks. The data set forth in table 3 show that approximately 900 hoppers were collected in 30 minutes in the unsprayed plot, compared to somewhat over eleven hundred and six thousand respectively in the nicotine tannate-sprayed plot and the lead arsenate–oil-sprayed plot. The hoppers were parasitized by *Aphelopus* sp. to the extent of 34 per cent in the unsprayed plot, 14 per cent in the nicotine tannate-sprayed plot and 1 per cent in the lead arsenate–oil-sprayed plot.

Table 3.—Number of leafhoppers caught in 30 minutes in three plots at Moorestown, and the percentage parasitized by *Aphelopus* sp.

Plot Treatment	No. Hoppers Caught in 30 Min.	No. Hoppers Examined	Per Cent of Hoppers Parasitized
Sprayed to petal-fall only	893	540	34
Lead arsenate–oil first brood, nicotine tannate second brood	1134	714	14
Lead arsenate–oil both broods	6238	716	1

Summary.—Codling moth eggs exposed for three days in a heavily sprayed orchard and in an unsprayed orchard showed low parasitism by *Trichogramma* sp. in the sprayed orchard and high parasitism in the unsprayed orchard. Codling moth larval and pupal collections in late summer in three orchards showed more parasitism in a heavily sprayed and weedy orchard than in a heavily sprayed and clean-cultivated orchard. An unsprayed and uncultivated orchard showed four and one-half times as much larval parasitism as either of the heavily sprayed orchards. Three plots of apple trees receiving different spray treatments following petal-fall varied in leafhopper population and the percentage of leafhopper parasitism. Low leafhopper parasitism was correlated with high leafhopper populations. The highest percentage of parasitism and the lowest leafhopper population was found on the plot receiving no spray treatment following petal-fall. The plot sprayed with lead arsenate–oil for first brood and nicotine tannate for second brood, while not as high in parasitism as the plot unsprayed following petal-fall, showed one-sixth the population and 14 times the parasitism found on the plot sprayed with lead arsenate–oil during first and second brood.

[7] 1918. Ohio Jour. Sci. 18(6):177. Apr.

A NEW AND EFFECTIVE CONTROL FOR APPLE FLEA WEEVIL

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The apple flea weevil, *Orchestes pallicornis* Say, first attracted the notice of Ohio apple growers about 1907, when it appeared in two adjoining orchards at Delaware in the central part of the state. These orchards were unique in another respect in that the owners had been following for some years a new system of cultural practice in which a heavy grass sod was allowed to develop and the mowed grass was used as a mulch beneath the trees.

During the interval since the first appearance of the apple flea weevil in destructive numbers in Ohio, the insect has increased its range until at present it is encountered in practically every apple-growing section of the state. In some orchards it has become the dominant pest, thereby exceeding in importance codling moth or any of the other better-known orchard enemies. Invariably an outbreak of this insect is preceded by several years of sod culture and is abetted if supplementary mulching immediately beneath the trees is practiced.

Development of an outbreak of apple flea weevil within a given orchard is insidious rather than spectacular in nature. At the outset a few tiny holes in the foliage are noticed, particularly on water sprouts and in leaves in the interior of the tree. Also, a few leaves bearing the blotched mines characteristic of the species are observed. As the insect increases in abundance from year to year the two types of damage become more apparent, until practically all the foliage is involved. Later the lower branches die, and finally the entire tree becomes so weakened that the quantity and quality of production diminish to the point where the orchard becomes unprofitable.

A considerable amount of experimental work has been directed against this pest. Early efforts indicated that the practice of absolutely clean cultivation could be relied upon as a specific control, but this procedure was found to possess certain limitations. In the first place, this type of orchard management is more expensive and such orchard activities as spraying and harvesting are less pleasant than in sod orchards. Moreover, the control of erosion is almost impossible in cultivated orchards in the hillier sections of the state.

Following the successful demonstration of clean cultivation as a control measure, burning the debris beneath the trees was suggested for the purpose of destroying the hibernating beetles. Several attempts to control by heat resulted in failure. The final efforts were made in the fall of 1934 and the spring of 1935 in cooperation with the federal Bureau of Agricultural Engineering. In this work, power burners were used that had proved eminently successful in the control of apple curculio in Kansas. Although as many as 30 minutes were spent beneath some individual trees, it was found that, because of the nature of the debris, far

too many beetles escaped; also, the method could not be considered practicable from the cost standpoint.

Endeavors to control with sprays or dusts were not very encouraging in the earlier stages of the work, although many materials and formulae were tried. The kerosene emulsion treatment developed by Flint of Illinois was the best, but it possessed a serious limitation in that treatments for both flea weevil and scab occur in the pre-blossom period and the materials to be used were not compatible. In addition, it was necessary to spread a canvas beneath each tree to be sprayed in order to wet thoroughly the insects which the process of spraying dislodged.

It was found also that trees to which lead arsenate was applied as an intended control in connection with the lime sulfur of the pre-pink and the pink sprays showed a definite reduction in damage from that apparent on trees sprayed with lime sulfur only. However, the effect was not adequate to control the outbreak where other factors were strongly favorable to the insect.

Preliminary laboratory experiments with insecticides indicated a high degree of toxicity of fluorine to the adults of apple flea weevil. On the basis of this work a comprehensive series of spray plots was executed in 1934 at Medina, Ohio, and repeated with slight modifications in 1935 at Medina and at Jackson, Ohio. In all three series, fluorine was outstandingly successful to the extent that in plots so treated flea weevil damage was reduced to a point considerably below that of significant injury. The formula used was:

Dutox or *Kalo* spray	5 lbs.
Flotation sulfur	8 lbs.
Goulac	3 oz.
Water	100 gals.

One application was made during the pre-pink period and another when the apple buds were in the full-pink stage. In each instance the under side as well as the upper side of the foliage was covered, with particular attention given to the inner portions of the tree. Plots sprayed with *Kalo* spray were slightly less damaged by flea weevil than were the *Dutox* plots.

The efficiency of fluorine in flea weevil control was further emphasized in the Medina orchard by reason of the fact that the owner, Mr. E. B. Blakeslee, sprayed a 25-acre block of mature trees in the pink and pre-pink periods with the fluorine–flotation sulfur–*Goulac* combination and obtained almost perfect control of both flea weevil and scab throughout the entire area.

An incidental aspect of both years' results was that the plots sprayed with either of the formulae were practically free from apple scab infection. This was particularly gratifying in 1935 because scab was unusually destructive in both orchards this last season.

James Cox, of the Department of Zoology and Entomology of the Ohio State University, has recently been appointed assistant entomologist at the Virginia Agricultural Experiment Station, Blacksburg.

EFFECT OF THRIPS ON POLLINATION AND BLOSSOM BLIGHT IN STRAWBERRIES

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The attack of thrips on the blossoms of the strawberry (*Fragaria*) was recognized by entomologists as early as 1887 when Forbes (*3*) said "the connection of thrips with the so-called 'buttoning' seems beyond dispute." Weed (*9*), working with Forbes, said "Upon examination you will find at least from a dozen to fifty or even a hundred or more living oblong objects, rushing and hurrying to and fro like rabbits in the bushes, or resting at receptacles, stamens, or pistils, eating and sucking the juices out of them." Newspapers of the time carried stories by growers who estimated that as high as 90 per cent of their crop was lost through damage by thrips. Quaintance (*4*) in 1898 states, "the damage to strawberries consists in chafing the stigmas and ovaries, thus causing the blossoms to turn brown, 'blight,' and eventually dry up." Further, "the damage will be greatest during times of drouth."

The above authors were correct in their observations of the injurious effect of large numbers of thrips on a strawberry blossom. However, they did not recognize the other causes of blighting and sterility and associated these with the damage done by thrips.

A reexamination of this problem in the light of our present knowledge of strawberry fruiting habits would indicate that thrips, *Frankliniella tritici*, are only in a limited way responsible for the so-called "blight" in strawberries.

The production of fruit by the strawberry is governed by many factors, including bud formation, character of fall and spring season, variety and age of plant, and nutrition. Ruef & Richey (*5*) state that "bud formation extends over a protracted period in fall months depending on age and plant vitality." Darrow (*2*) says "The character of the fall season is considered one of the important causes of fertility and sterility in the fruit." Valleau (*7*) in 1918 states that "there is a correlation between flower position and fertility of pistils, fertility decreasing in the later flowers of an inflorescence." In 1923, he said that "In *Fragaria*, as in many other forms, the sex of all flowers of any given plant is not necessarily the same. It is quite common in the perfect-flowered varieties for practically all the earliest flowers to be female. Male flowers, on hermaphroditic varieties, are common and are practically always limited to the last flowers of a cluster to bloom. Completely sterile flowers are not uncommon among later flowers of a female inflorescence." Cummings & Jenkins (*1*) state that "Sterility in the strawberry as now understood appears to be largely a matter of sex inheritance." Vaile (*6*), in experiments paralleling the work of the author, found that "abortion of pollen and pistils may be controlled, in part, by placing the plant in a favorable environment."

From observations for years 1932, 1933 and 1934, thrips feed on open flowers and confine their attack largely to the bases of the stamens. The

damage appears shortly after feeding as discolored brownish areas at the bases of these structures. Heavy feeding will be indicated as a blackened ring which often completely surrounds the pistillate portion of the flower. Only occasionally were thrips found to attack the pistil proper, and open flowers only are damaged.

Seasonal population.—The thrips (98 per cent of them *Frankliniella tritici*) are associated with strawberries during the bloom only. Previous to strawberry bloom thrips can be collected in enormous numbers from other flowers, for example apple, pear, cherry, small fruits, dandelion, etc. When strawberries bloom they drift to the beds in enormous numbers, oviposition begins at once, and by the end of bloom (about 30 days) young are maturing. The thrips disappear from the beds as the plants cease to bloom.

Thrips population studied.—At regular intervals blooms were collected and the thrips they contained concentrated by aid of Berelese funnels. Typical collection through the season yielded per bloom .03 to 1.2 thrips the first week; .3 to 21 the second week; 4 to 11 the third week; 15 to 41 the fourth week. The maximum period of flower production occurs during the second and third weeks, at which time the number of thrips per bloom decreases. During the fourth week blooming rapidly ceases, with a concentration of both young and adult thrips in the few blooms that remain. In this study the thrips population was well over four thrips per bloom from the second to fourth week.

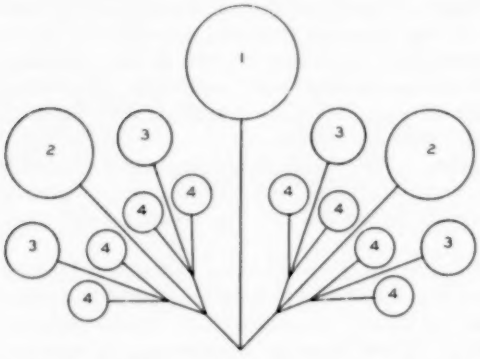

Fig. 1.—Diagram to show the normal arrangement of flowers produced by the strawberry. Order of bloom is indicated by numbers 1–4.

Early in the study it was found that the various flowers produced by an individual plant responded differently. The typical flowering order in strawberry is shown in fig. 1. On an especially vigorous plant all flowers may be produced, although rarely do they all bear fruit. The first and second group of flowers, if pollinated, dominate. According to the plants' ability to produce, a part of the third and fourth group may fruit.

Cage experiments.—Individual flowers and groups of flowers were caged with and without thrips. (Paper bags and glass cylinders made satisfactory cages.) Where thrips in excess of five per flower were present, only vigorous first and second blooms set fruit. Noninfested blooms set a greater number of fruits, but invariably the excess numbers of fruit set were aborted within about 10 days, leaving on the average fruits from the strong blooms comparable with the infested cages. Table 1 gives data supporting these findings under cage conditions.

Field tests.—Field population studies indicated that thrips were present through the season in sufficent numbers to damage blooms, as shown by cage experiments with known numbers of thrips. To determine the extent of damage in the field, at intervals the flowers that belonged to the various bloom orders were tagged. All bloom orders were present throughout the season except at the start and at the finish. Table 2 gives

Table 1.—Typical pollination of blooms under cage conditions.

Variety	No. Cages	No. Blooms	No. Thrips per Bloom	Percentage of Pollination by Order of Bloom				
				1	*2*	*3*	*4*	Average
Dunlap	3	180	0	26	37	4	0	15
Dunlap	3	188	9	37	13	0	0	8.5
Reasoner	5	19	0	Initial pollination 82%				24
Reasoner	13	60	10	Initial pollination 20%				20

a summary of three years' observations including blossoms tagged at known dates and fruiting clusters collected at the end of the seasons. A comparison will show that essentially the two methods do not vary widely. It is evident that the ability to set fruit is definitely related to blooming order and plant vigor, and not related to thrips population. This is shown by the fact that the first bloom borne by a plant will pollinate irrespective of thrips, the second bloom to a lesser extent, the third still less, and the fourth will seldom pollinate. Varieties differ

Table 2.—Normal field pollination. The first five lines are flowers tagged throughout season of bloom; lines 6–10 are fruiting clusters selected at random at close of season, before fruit ripened.

Year	Variety	No. Fruiting Clusters	No. Bloom Records	Percentage of Pollination by Order of Bloom				
				1	*2*	*3*	*4*	Average
1932	(Average of twelve)		147	83	62	49	12	56
1933–4	Premier		329	99	88	46	8	75
1933–4	Burrill		313	89	78	34	22	70
1933–4	Blakemore		371	88	78	44	5	67
Total			*1160*	*91*	*79*	*43*	*11*	*69*
1933–4	Premier	200	1158	100	94	33	0	65
1933–4	Blakemore	200	1802	96	75	34	7	41
1933–4	Burrill	200	2180	98	76	33	1	36
1934	Dunlap	100	943	95	67	48	0	34
Total		*700*	*6083*	*96*	*78*	*36*	*2*	*43*

widely in the manner of fruit production. For example, Premier bears mostly first and second blooms, while Burrill has abundant thirds and fourths.

A comparison between the seasonal pollination and thrips population shows that a first bloom produced late in the season is equally apt to pollinate as an early bloom. The same is true for the second blooms. The thirds usually appear near the middle of the season, pollinate weakly at first, and later not at all. The fourth appear quite late and being weak to start with are easily injured by thrips. As mentioned, the blighting or abortion of these late blooms is normal even though pollination has occurred. The plant apparently pollinates, even with thrips, an excess number of fruits. These excess fruits are aborted and never mature.

The work of other authors indicates that the ability to bear fruit is correlated with inherited and environmental factors. Crop yields are determined in most situations months ahead of the actual season of bloom and pollination. Plants normally pollinate in excess of the numbers of fruits they are normally able to mature. Abortion, or "blighting" of a part or all of the blooms produced by a plant, is a normal procedure, the degree of abortion depending on the conditions of heredity and environment under which the plant exists.

Summary.—Thrips drifting into strawberry beds cause the thrips population to increase rapidly during the early bloom; during the height of bloom their numbers decrease per bloom; their numbers increase rapidly late in the season when few blooms are present.

Both laboratory and field experiments with thrips indicate that the so-called "blight" occurs on infested and weak blooms, the stronger blooms pollinating and producing fruit irrespective of thrips populations.

Thrips are only a minor limiting factor in the pollination and the production of fruit under field conditions.

Pollination in strawberry is strongly associated with the order of bloom.

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STUDIES OF SEASONAL OCCURRENCE OF INJURIES TO POTATO TUBERS IN WESTERN NEW YORK

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Investigations of potato tuber defects have been conducted in Monroe county, N. Y. during the past four years. Early in these studies it became apparent that the abundance of tuber injuries from the different pests involved varied at different dates during the maturing season. It is the purpose of this paper to present data obtained in an effort to ascertain whether the different injuries occurred in any consistent relation-

ships to each other, and to discover possible methods whereby the quality of the crop might be improved.

The defects considered were scab, scab-gnat, and millipede injuries. These injuries are fairly distinct in their characteristics. As described by Barrus & Chupp,[1] scab appears on young tubers as "a small, gradually enlarging, reddish or brownish raised spot." As ordinarily observed at harvest, scab spots are "brownish roughened areas, more or less circular and with irregular margins. They may be raised somewhat above the

Table 1.—Percentage of tubers injured by scab, scab-gnat and millipedes during the last six weeks before harvest.

	Date of Examination					
	Aug. 31	Sept. 8	Sept. 18	Sept. 25	Oct. 3	Oct. 10
			Percentage of Tubers Uninjured			
1932		41.78	25.2	35.65	32.58	35.85
1933	32.62	20.55	22.3	18.75	18.6	11.56
1934	52.38	30.95	26.1	20.17	15.47	19.4
1935	14.67	20.15	13.08	14.4	11.1	9.9
Ave.	*33.22*	*28.46*	*21.67*	*22.24*	*19.44*	*19.18*
			Percentage of Scab Injuries			
1932		46.98	41.67	27.38	24.3	20.1
1933	55.33	59.75	56.52	43.46	41.28	31.92
1934	41.76	56.73	53.57	31.02	28.17	16.48
1935	80.2	63.8	64.48	37.7	32.88	21.43
Ave.	*59.1*	*56.81*	*54.81*	*34.89*	*31.66*	*22.48*
			Percentage of Scab-gnat Injuries			
1932		40.75	43.77	42.95	35.43	38.7
1933	15.35	39.97	36.82	38.27	39.47	29.96
1934	3.72	14.57	34.95	44.8	34.67	29.95
1935	52.54	44.98	49.55	49.43	49.48	48.93
Ave.	*23.87*	*35.07*	*41.27*	*43.86*	*39.76*	*36.88*
			Percentage of Millipede Injuries			
1932		6.25	20.2	31.45	39.1	35.87
1933	7.1	26	49.6	56.97	59.73	63.02
1934	2.8	8.2	30.25	59.18	61.52	65.65
1935	22.13	31.85	57.13	64.3	71.75	80.3
Ave.	*10.68*	*18.08*	*39.05*	*52.98*	*58.02*	*61.21*

healthy skin, or may be more or less sunken." The scab-gnat injuries, caused by larvae of sciarid flies, typically extend more deeply into the flesh of the tubers, and the small cavities are usually filled with the frass-like excrement of the feeding larvae. The feeding activities of millipedes leave rather large, shallow, open cavities, usually somewhat irregular, and with little or no overhanging epidermal tissue.

In the region where these investigations were conducted, tuber setting and formation were well under way early in August, and by the last of the month many tubers had reached an appreciable size. Certain injuries normally became apparent somewhat earlier than this, but characteristic lesions caused by the different pests did not occur in any abundance much before the first part of September. The crop is normally harvested during the second or third week of October.

[1] 1926. Potato diseases and their control. N. Y. (Cornell) Coll. of Ag. Ext. Bul. 135:91.

Beginning about the time these injuries first appeared, a series of fields was examined at approximately weekly intervals and injury counts made in each field. Three definite counting stations were located at random in a field and at each station consecutive plants in one row were dug until from 12 to 20 tubers of a minimum size of about 1½ inches in diameter were obtained. The injuries on these tubers were tabulated, and the data obtained from the three stations were combined and averaged to give the weekly count in that field, based upon counts of from 36 to 60 tubers. Once each succeeding week counts were similarly made at the same three stations. In the fall of 1932 during the last five weeks before harvest, data were obtained from four widely scattered fields within the area. Similar data were likewise obtained from six fields during the last six weeks before harvest in both 1933 and 1934. In 1935, four fields were examined weekly during the last six weeks previous to harvest.

These data thus obtained have shown fairly consistent trends for the four seasons, as will be seen by consulting table 1, which shows the approximate dates of field examinations, the average per cent of uninjured tubers and of tubers injured by scab, scab-gnats and millipedes for each of the four years. It will be noted that there was a definite tendency each year for the per cent of uninjured tubers to decrease as the season advanced. This tendency is shown in fig. 1. The points shown on the curves represent the average figures for all fields for the dates shown in each of the four years. The curve showing the percentage of scab-injury indicates that there was a definite reduction in the proportion of tubers showing scab lesions throughout the maturing season. Observations show that scab reached a maximum at about the first date shown on the chart, this date varying somewhat from year to year. Injury from scab-gnats did not usually become abundant until a week or two after maximum scab infection. This injury continued to occur in about the same proportion, but finally showed a consistent decrease toward the end of the season. The data on millipede injuries are more consistent for the four seasons than are those of any of the other injuries. Each year millipede injuries were low early in the season, but just after maximum scab infection occurred, the pro-

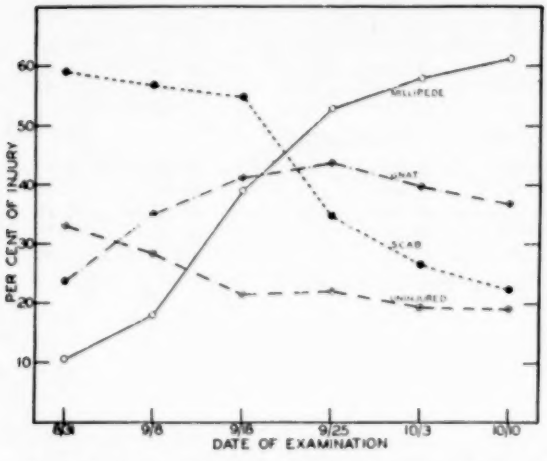

Fig. 1.—Seasonal incidence of occurrence of injuries to potato tubers by scab, scab-gnats and millipedes during the four-year period 1932–35.

portion of tubers injured by millipedes increased markedly. This increase in the per cent of tubers injured by millipedes continued throughout the season, but the rate of increase slowed down materially near the end of the maturing season.

Comparison of these records presents some interesting relationships. The curve showing the percentage of uninjured tubers indicates that there was a constant decline in the proportion of clean tubers as the season advanced. A reduction of scabby tubers as shown here has been reported by others,[2] but the decreases were of much smaller magnitude than those obtained in the investigations here reported. A possible explanation advanced for this reduction in scabby tubers was that the infected tubers did not develop, or that they were reabsorbed more readily than the healthy ones. It was also suggested that the tubers simply outgrew the scab. Records of injuries presented in table 1 and fig. 1 were secured from tubers of not less than $1\frac{1}{2}$ inches in diameter and since only typical lesions were counted, the above-mentioned hypotheses probably would not account for the large decreases in tubers injured by scab and gnats in the Monroe county investigations. From the data here presented, it appears more probable that the millipedes were feeding upon the scab lesions. This explanation would account for the decrease in scab as shown, and also for the consistent increase in millipede injuries. Apparently scab-gnat injuries to tubers followed scab infection, but since the proportion of injured tubers remained constant during the middle of the season and later actually decreased, it appears that millipedes also fed on the portions of the tubers injured by scab-gnats.

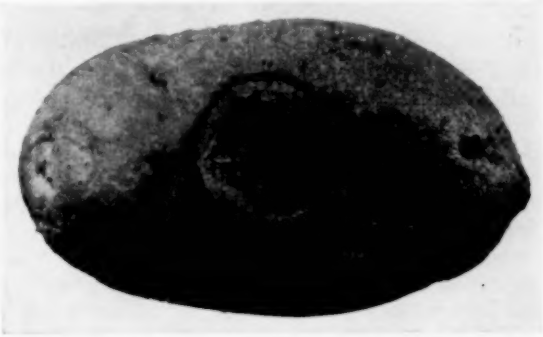

Fig. 2.—Marked scab lesion on a potato tuber after being exposed to millipedes.

The relationship between potato scab and millipede feeding injuries has been further illustrated by placing tubers with typical scab lesions and uninjured tubers in containers along with millipedes. The margins of the scab lesions were previously marked on the surface of the tuber with India ink. In a small series of 25 such experiments, practically every marked lesion showed evidence of millipede injury at the end of three weeks and in no case did the unmarked, clean tubers show any injury. Fig. 2 is a photograph of one of the marked scab lesions after the tuber had been exposed to millipedes.

In conclusion, it is evident from the data shown that millipede injuries to potato tubers are secondary in nature, in that they follow other,

[2] **Mader, E. O.** and F. M. Blodgett. 1935. Potato spraying and potato scab. Am. Potato Jour. 12:137–42.

primary injuries. Logically the reduction of these primary injuries would result in corresponding reductions of the millipede injuries. In regions where millipede injuries are an important factor in reducing the quality of potato tubers, the data indicate that the crop should be harvested as early in the season as possible.

SHADE-TREE INSECT DEVELOPMENTS

E. P. Felt and S. W. Bromley, *Stamford, Conn.*

There was an extraordinary abundance of the eastern tent caterpillar *Malacosoma americana* in the northeast, and in many localities comparatively little was done until the caterpillars were nearly grown and defoliation well advanced. The demonstration of feeding possibilities had its effect and belated action was attempted in some places even though the caterpillars had commenced to wander. The lesson was so firmly impressed on one New York village that it passed an exceedingly drastic law reading in part as follows:

"It shall be unlawful to any owner of any occupied or unoccupied lot or land or any part thereof . . . to permit or maintain on any such lot or land, any trees, shrubs or bushes or parts thereof which are or may become infected or infested with caterpillars, tent caterpillars, insects or other creeping segmented animals, which cause or tend to cause disease, destruction or damage to such trees, shrubs or bushes by devouring the bark or foliage thereof, and which spread by passing from such trees, shrubs or bushes, to other trees, shrubs or bushes, thereby causing destruction and damage to the property of others and becoming an unsightly and public nuisance." Those not complying with the ordinance are declared guilty of disorderly conduct and upon conviction become liable to a penalty not exceeding $100 for each offense, each day upon which such violation continues constituting a separate offense.

More recently, a borough in New Jersey passed an ordinance providing for one or more inspectors who shall have the right to enter upon any and all lands within the borough to ascertain the prevalence of tent caterpillars and if they are found devouring foliage on trees or if their "tents" or "nests" are allowed to reach such size as to be judged unsightly and/or if the larvae of the tent caterpillars are feeding on the foliage of trees and shrubs other than the parent plant on which they were hatched, the property owner or occupant of the premises shall be notified and be liable to a fine not exceeding $20.

Probably other ordinances were enacted for the correction of this condition. These two are cited as examples of the effect a severe tent caterpillar outbreak may have in first-class residential communities.

Reports from New England and New York localities indicate an abundance of this insect next spring, though it may not be so generally prevalent as last spring.

A gall wasp, *Neuroterus irregularis*, developed in immense numbers on a few oaks at Greenwich and Stamford, Conn. In one case a branch less than three feet long and remarkable because of its somewhat peculiar

appearance had the weight and feeling of an apple tree limb fairly well-loaded with fruit. There were on this small branch more than twenty irregular masses of juicy tissue, ornamented or trimmed, as it were, with rudimentary leaves. Each of the masses had a diameter of two to three inches and contained numerous gall wasp larvae. In one instance two chestnut oaks, some thirty feet high, had most of the foliage transformed from the normal leaf structures to fleshy, irregular galls. The galls of this insect were also reported as being exceptionally abundant in eastern Massachusetts.

The oak pill gall, *Cincticornia pilulae*, was observed in exceptional abundance on a number of species of red oaks at Tuxedo, N. Y. the leaves of the lower branches being thickly, and in some instances quite thickly, infested. There was also an unusual abundance of this species in the Boston area.

A pine leaf midge, tentatively designated as *Cecidomyia*, has been mentioned several times in earlier years on account of its injuries to white and Scotch pine. It was reared last spring and it presents the general characteristics of a European species, though it is impossible to be certain of its identity therewith, owing to the non-existence of sufficiently detailed descriptions and the probable loss of types, therefore it will be described as a new species. The injury of the past season was less than that of last year, though circumstantial evidence indicates that this insect has been gradually extending its range. The pale yellowish maggots occur in the needle bundles and weaken the bases of the needles. They frequently cause a bending near the middle of the affected needles and later the dropping of the entire bundle. This latter may involve 50 or 75 per cent of the foliage on individual trees. It is impossible to predict the status of this midge. There is a possibility that it may be controlled by parasites several years after the primary infestation.

An unusual though not particularly important record was the rearing of hundreds, possibly thousands, of tiny midges, *Miastor americana*, from sections of dying elm limbs collected at Wilton, Conn. last spring. During the entire month of September there was a large production of these flies which are of interest largely because of their pedogenetic habits. It is quite possible that this species may be relatively abundant in areas where there are many sickly and dying elms.

A birch case bearer provisionally identified as *Coleophora salmani* was found the last of June, rather seriously damaging gray birch just outside of Pittsfield, and also in small numbers at Williamstown, Mass. This species has not been reported previously outside of Maine. It is recorded as a serious pest in the Bar Harbor region.

The finding of the European spruce sawfly, *Neodiprion polyotomum*, in several localities in western Connecticut, western Massachusetts and the recent report of its presumably general occurrence in northern New England and the Adirondacks indicates a wide dissemination of this insect since it was found in the Gaspé Peninsula in 1931. There is a report of heavy defoliation in the Gaspé area in 1935 and a statement to the effect that 75 per cent of the spruce in the infested area are dead from the work of this insect and a bark beetle. It is quite within possibilities that

the sawfly work has produced conditions favorable to scolytid invasion. The sawfly larvae feed by preference upon the old needles, producing an obviously sparse foliage and a tufted appearance on the small twigs. This latter is undesirable in the case of ornamentals and if Norway spruce become somewhat generally infested, which is distinctly within possibilities, this spruce sawfly may become an injurious pest of ornamentals.

The European beech scale, *Cryptococcus fagi*, became established in eastern Massachusetts several years ago and more recently it was found in southern Connecticut, southern New York, and it possibly occurs in northern New Jersey. This scale insect is not of itself a serious pest. It is, however, dangerous in that the feeding by this scale apparently produces conditions favorable to invasion by a nectria. The scale-nectria combination has been followed in Nova Scotia by a 90 per cent infestation of beech over three inches in diameter, and the killing of 50 per cent of the trees. A recognition of this as a probability indicates the need of discovering and controlling infestations of the beech scale before the nectria invasion develops.

The Japanese scale, *Leucaspis japonica*, is a comparatively unknown species, yet it is becoming increasingly abundant in the greater New York area. It is narrower and smaller than the oyster-shell scale, it having a length of only about one-sixteenth to one-twelfth of an inch. It occurs somewhat commonly on soft maple, Norway maple and privet, and in a badly infested area on Long Island it was mostly killed by the extreme temperatures of 1933–34. The soft maple appears somewhat tolerant of this scale insect. Branches four inches in diameter may have much of the bark area practically covered by the scale and not be seriously affected, though indications are that a continuance of this condition over several seasons is likely to result in killing of good-sized branches.

Plant lice have been unusually abundant and injurious to pines. White pines were badly infested by a dark brown, white-lined plant louse, *Dilachnus strobi*. A bad infestation by this insect has been somewhat definitely associated with greatly reduced vitality and even the dying of small trees.

Last year a mugho pine was found in a decidedly sickly condition and there was no clue to account for this. The past season a serious infestation by a plant louse, identified by Professor Miriam A. Palmer as *Eulachnus rileyi* Williams, was discovered and definitely associated with a weak, unhealthy condition. The tree was literally overrun with the small, active plant lice which, unlike most other aphids, move about rapidly and travel readily over hands and portions of garments brought close to the infested twigs. The insects occur along the needles, singly or in rows, and produce yellowish spots which enlarge. Shortly the discolored needles drop. In early October a large proportion of the needles of last year had fallen or were yellowed to such an extent that they are likely to drop shortly. Similar conditions on mugho pines were reported from the Philadelphia area.

The Norway or red pine was also infested to a slight extent with another plant louse but this insect was not associated with material injury.

AN EXPERIMENT FOR THE CONTROL OF JUNIPER WEBWORM[1]

DICHOMERIS (YPSOLOPHUS) MARGINELLUS Fab.

M. G. FARLEMAN, *Michigan State College, East Lansing*

On September 4, 1935, a local nurseryman reported that all his juniper trees were infested by numerous small larvae. Examination showed that a large block of Irish juniper was rapidly becoming unsalable, due to attack by the larvae of the juniper webworm, *Dichomeris marginellus*, which in their feeding cause the browning and death of needles. This damage in heavy infestations may cause serious losses from defoliation. However, aside from quarantining, the principal loss from this insect results from the larval habit of webbing the damaged foliage together, causing it to remain upon the tree in unsightly masses, which are sometimes felted together by the tight silken tubes spun in the last larval stage. Approximately 50 to 75 per cent of the larvae were already within such tubes when treatment was undertaken.

All spraying operations were done with a 50-gallon barrel sprayer developing a pressure of 250 pounds. Two 50-foot hose extensions were used from the spray rig to the rows of juniper trees. The spray solution was forced in among the inner branches with a regular orchard type, single-nozzle spray gun with a nozzle well open to insure a driving forceful spray. The nozzle was moved about at various angles at short distances from the trees, producing a swaying branch movement that allowed suitable penetration and complete coverage.

Plot 1.—On September 4, 1935, a spray consisting of nicotine sulfate 40 per cent, diluted to a strength of 1:400 and using a sulfated higher alcohol spreader[2] at the rate of 6 ounces in 100 gallons, was applied to 200 junipers of 3 to 6 feet in height. The trees were vigorous and in good condition except that the inner branches were heavily matted by webworms.

Plot 2.—Also on September 4, 1935, the remainder of the juniper stand, numbering about 200 trees, was sprayed with *Loro* diluted to a strength of 1:400, using a sulfated higher alcohol spreader[2] at the rate of 6 ounces in 100 gallons.

After an interval of 14 days, the sprayed plots were checked and it was found that the *Loro* applications were not a success. Hurried arrangements were made for a second application since the nursery foreman was anxious to have the infestation controlled. Time did not permit taking accurate counts on both plots but examination showed that the *Loro* plot required further treatment. As a safeguard, both plots were sprayed a second time, using nicotine sulfate with the same spreader[2] and at the strength previously employed.

On September 25, 1935, counts were made to determine the degree of control. Samples of twigs were taken from the top, side and bottom of

[1] This article is authorized for publication as Journal article 248 by Michigan Agricultural College Experiment Station.

[2] Grasselli Chemical Company 1-N-438.

each tree and each larval nest torn apart. The majority of these twigs, ranging from 3 to 6 linear inches, possessed three to eight larvae. Of the 725 larvae found in these samples, 694 or 95.7 per cent, had been killed.

No spray injury to the juniper foliage was observed during the course of the experiment.

PINE-TIP MOTHS OF SOUTHERN OHIO

J. B. Polivka, *Portsmouth, Ohio,* and J. S. Houser,
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During the years 1934 and 1935, an insect survey of the pine plantings of the state was made through the cooperative efforts of the Civilian Conservation Corps organization of the Ohio Division of Forestry and the Department of Entomology of the Ohio Agricultural Experiment Station. All classes of insect depredators were studied, but particular attention was given the tip moths attacking pine.

Undoubtedly, the pine-tip moths have been in southern Ohio for many years, as is evidenced by the dwarfed and double-branched injury so noticeable in some of the native pines and also in some exotic species in certain localities. However, the survey revealed for the first time the identity of the insects responsible for the damage. These were found to be the Comstock tip moth, *Rhyacionia comstockiana* Fern., the Nantucket tip moth, *R. frustrana* Comst., and the Zimmerman tip moth, *Pinipestis zimmermanni* Grt. These insects cannot be listed in the order of their economic importance as the infestation is variable in different areas in southern Ohio. The European pine-shoot moth, *Rhyacionia buoliana* Schiff., was not taken in that part of the state.

The term "tip moth" has not been generally accepted in references to the first three species mentioned but for convenience will be employed in this discussion. The type of injury caused is typical of each species.

The larva of the Comstock tip moth attacks the leaders a few inches below the tip, producing a pitch mass from which it enters the twig. It tunnels downward in the twig for a distance of three or four inches and when mature returns to the pitch mass, in which the pupal stage is passed. After the moth emerges the protruding pupal case remains.

The larva of the Nantucket tip moth begins by spinning a web mixed with resin around the buds and finally the bud itself is entered. Usually several individuals attack the same bud and work downward, finally killing the first two or three inches of the branch. The pupal stage is spent within the tunnels in the tip.

The larva of the Zimmerman tip moth enters the leader near the tip but no pitch mass results, as is the case with the Comstock tip moth. However, it frequently occupies twigs infested by the latter. Usually several inches of the damaged branch are hollowed out and only a shell remains. If the larva does not pupate within the twig, it leaves its tunnel a short distance from the lower end and pupates elsewhere on the tree. It is common to find a large percentage of this species pupating in the old pitch masses resulting from the work of the yellow-bellied sapsucker.

The distribution of the tip moths has been found to extend over the entire range of the native pine in southern Ohio. The Comstock and the Nantucket tip moths have been found also in the plantings of the Scioto Trail and Pike forests, which are about 15 miles north of the native pine area. However, these insects were not found in other plantings of the same species of pine from the same nursery 70 miles north of native stands. This indicates that the tip moths had not been distributed to the Scioto Trail and Pike forests through nursery stock but that the adults had flown from the nearest native stand, 15 miles distant.

In view of the fact that the tip moths are found in susceptible species of native pines throughout their entire range in the state, it would be

Table 1.—Percentage of pine species infested with the pine-tip moths in southern Ohio in 1934 and 1935, and the average number of infested tips per tree in 1935.

Species of Pine	Zimmerman Tip Moth			Nantucket Tip Moth			Comstock Tip Moth		
	Per Cent Infested Trees		Av. No. Infested Tips per Infested Tree	Per Cent Infested Trees		Av. No. Infested Tips per Infested Tree	Per Cent Infested Trees		Av. No. Infested Tips per Infested Tree
	1934	*1935*	*1935*	*1934*	*1935*	*1935*	*1934*	*1935*	*1935*
				In Plantings					
Scotch	8.7	1.2	1.5	0	.1	1		.7	1.4
Red	3.5	1.3	2	.5	.3	1.6		.1	1
Japanese Red		2	3.6						
Corsican	.6	1.9	1		.3	2		.4	1
Jack	3	3.8	1.8		3.8	2.8		9.3	1
Lodgepole								5.7	1
Ponderosa	9.1	.9	1.5					17.2	2.1
Swiss Mountain	8	10	1						
Loblolly					20	1.8		3.3	1
Shortleaf	3.3	.4	1.8	.1	4.5	1.6			
Pitch	18.3	24	2.6					2.7	1.5
				In Native Stands					
Shortleaf					7.9	2.6		7	1.3
Pitch		18	2.6		3.3	1.9		34.1	2.6

reasonable to assume that plantings within the area likewise would be be infested, at least to some extent. During the course of the survey, in which approved plot-sampling methods were used, the following species of pine were found to be infested: Scotch, *Pinus sylvestris* L.; red, *P. resinosa* Sol.; Japanese red, *P. densiflora* Sieb. & Zac.; Corsican, *P. nigra* var. *calabrica* Schneid.; jack, *P. banksiana* Lamb.; lodgepole, *P. contorta* Doug.; Ponderosa, *P. ponderosa* var. *scopulorum* Engel; Swiss mountain, *P. mugho* Turra; loblolly, *P. taeda* L.; shortleaf, *P. echinata* Mill.; and pitch, *P. rigida* Mill.

In table 1 are shown the infestation percentages of the several pine species examined during the course of the 1934 and 1935 surveys and also the average number of damaged leaders per infested tree found in 1935. The insect survey was started too late in the spring of 1934 to obtain conclusive data on the Comstock tip moth; therefore no record is given for this insect for that year.

The Austrian pine, *Pinus nigra* Arnold, native Jersey scrub pine, *Pinus virginiana* Mill, and white pine, *Pinus strobus* Linn., are all found in native stands or in plantings in southern Ohio, but no tip moths were found in the sample plots used in the survey. However, when the senior author walked through the stands later, a few infestations of Zimmerman

Table 2.—Locality infestation data on the most seriously infested species of pine.

	Zimmerman Tip Moth		Nantucket Tip Moth		Comstock Tip Moth	
	Per Cent of Trees Infested	Av. No. Infested Tips per Infested Tree	Per Cent of Trees Infested	Av. No. Infested Tips per Infested Tree	Per Cent of Trees Infested	Av. No. Infested Tips per Infested Tree
Pitch Pine in Plantings						
Shawnee forest	38.8	2.8			4.7	1.5
Scioto Trail forest	0				0	
Waterloo forest	10	1			0	
Marietta forest	0		25	2.8	60	2.3
Pitch Pine in Native Stands						
Shawnee forest	10	3.3			34.6	2.8
Hocking forest	47.6	1.6			47.6	1.3
Dean forest	10	1.3			6.7	1.5
Marietta forest	40	1.8	23.3	1.9	50	2.3
Shortleaf Pine in Plantings						
Shawnee forest	1.6	1.8	0		0	
Marietta forest	0		42.9	1.8		
Dean forest	0		0		0	
Pike forest	0		85	9.9		
Zaleski forest	0		2	1		
Waterloo forest	0		7	1		
Hocking forest	0		2.6	1		
Scioto Trail forest	0		.6	2		
Shortleaf Pine in Native Stands						
Shawnee forest	0		0		7.1	1.3
Marietta forest	0		45	2.6	10	1
Dean forest	0		0		0	
Loblolly Pine in Plantings						
Scioto Trail forest			10	3.5		
Marietta forest			25	1.5	5	1
Ponderosa Pine in Plantings						
Shawnee forest	0		0		8	1.2
Hocking forest	0		0		28	1.7
Dean forest	0		0		48	2.4
Scioto Trail forest	0		0		0	

tip moth were found in Austrian pine and, similarly, Comstock and Nantucket tip moths were found in Jersey scrub. No instance of tip moth damage to white pine was noted, although the literature contains a number of records of serious damage to this species by Zimmerman tip moth.

In analyzing the data in table 1 it will be seen that, with one exception,

those species of pine most nearly indigenous to the area—pitch, shortleaf and loblolly—were most seriously infested. The exception is Ponderosa pine, which is probably the furthest removed from its native habitat of all those studied. In some areas, where pitch pine stands have developed through natural reproduction in abandoned cultivated fields, few trees have a dominant terminal leader but are much branched and bushy. The Ponderosa pine is the most seriously damaged exotic species of all those studied. In one planting in the Dean forest, the Comstock tip moth has infested the tips of so many twigs that the trees resemble high shrubs instead of trees.

The degree of tip moth abundance is not constant for all sections of southern Ohio. As pointed out in an earlier paragraph, abundance or scarcity of native pine stands may be the dominating factor. Table 2 indicates the relative abundance of tip moth in the several general areas which were studied.

The data in the foregoing table show that there is a close correlation in the several areas studied between the degree of infestation in the native stands and plantings. In the Dean forest it seems that the tip moths prefer the plantings of Ponderosa pine to those of shortleaf pine.

There has been no opportunity for detailed life-history studies of the tip moths in southern Ohio, but it is hoped that this phase of the work may be given attention in the near future. Pertinent observations have been recorded from time to time, and on the basis of these the following statements can be made.

The Comstock tip moth and the Zimmerman tip moth have but one annual generation, and the Nantucket tip moth has two.

The adults of the Comstock tip moth emerged in 1935 from May 25 to the middle of June. The first adults of caged Zimmerman tip moth material emerged about July 4 in 1934 and continued to appear until August 10, whereas in 1935 the first emergence was recorded on July 25. The 1935 first-generation adults of the Nantucket tip moth began to emerge in April and those of the second generation in July. The overwintering pupae were found as early as August.

Summary.—With the exception of white pine, all species of pine studied, either in native stands or in plantings, were found to be infested with one or more of the three species of tip moth that are found in the area.

With the exception of Ponderosa pine, those species most seriously infested are those whose native habitat most closely approaches that of the area studied.

There is a correlation between abundance of native pine, infestation of native pine, and infestation of plantings of pine species similar in susceptibility to native sorts.

In some areas, tip moths have caused significant damage both to native stands and to planted areas.

The variation in infestation from one year to another by any one species of tip moth may be due to parasitism, but up to now there are no data on this point for southern Ohio.

DUST TREATMENTS FOR PROTECTING BEANS FROM THE BEAN WEEVIL

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Experiments were set up in December 1933 to test the efficiency of certain materials and the minimum effective dilutions of each in preventing infestations of navy beans by the common bean weevil, *Mylabris objectus* Say.

Preliminary tests.[1]—In these tests a pound of navy beans mixed with the material to be tested was placed in an unclosed paper bag. The various bags were placed in a cabinet where they were accessible to thousands of bean weevils. The test was carried on from December 1933 to February 1935. Fifteen materials were used, eight of which (coal ashes, wood ashes, Anderson clay, Dawson clay, *Dutox* or 80 per cent barium fluosilicate, white wheat flour, hydrated lime and dusting talc) gave perfect or nearly perfect protection when used at dilutions of 1:1 or one part material to two parts beans by volume, and were selected for further tests which are reported in detail in this paper.

The materials used in the preliminary tests, but not in the final tests, and the results obtained after the beans treated with them were exposed to the attack of weevils for 15 months, are: (1) Bayer dust one part to 384 parts beans by weight, 3.7 per cent of beans infested; (2) borax one part to 32 parts beans by weight, 75.4 per cent of beans infested; (3) copper carbonate, one part to 48 parts beans by weight, .7 per cent of beans infested; (4) U. S. P. *Cresol* one part to 10 and one part to 20 parts beans by weight, 39 and 78 per cent of beans infested; (5) *Dendrol* one part to 10 parts and one part to 20 parts of beans by volume, 12 and 29 per cent, respectively, infested beans; (6) *Orthol K* one part to 10 parts and one part to 20 parts of beans by volume, 13.5 and 21 per cent infested beans; (7) dusting sulfur one part to 14 parts of beans by weight, 8 per cent infested. Five untreated bags of beans which served as checks showed an average of 43.5 per cent infestation.

Procedure.—In the final tests, here reported in detail, coal ashes, wood ashes and white wheat flour were each used at the rate of one part to 2, 4, 10, 25 and 50 parts of beans by volume. Anderson clay, Dawson clay, *Dutox*, hydrated lime and talc were each used at one part to 4, 10, 25, 50 and 75 parts of beans by volume. Five hundred beans were used in each test and the tests were replicated three times.

The beans for each test and the proper amount of dust were placed in a jar and shaken vigorously so that each bean would come in contact with the dust. They were then poured into a pound paper bag which was left open. No material was placed on top of the beans in the bags. At 1:50 and 1:75 dilutions there was little more than enough dust to coat the individuals beans. The bags of each replication were placed in rows in a tray. Those of each dilution were placed at random in the same row,

[1] These were set up by L. I. Musgrave, then a graduate student in Purdue University.

the position of the rows being selected at random. A bag of 500 untreated beans to serve as a check was placed at random in each row. The three trays were then placed in a cabinet. Beans heavily infested with bean

Table 1.—Results of treating beans with dusts to prevent infestation by bean weevils at household temperatures, Lafayette, Ind., May 1 to November 1, 1935.

Material	No. Replications	Ratio of Material to Beans by Volume	No. Beans	No. Infested Beans	Av. No. Exit Holes per Infested Bean	No. Dead Weevils in Bags	Per Cent Infested Beans
Ashes, coal	3	1:2	1500	0		49	0
Ashes, wood	3	1:2	1500	0		113	0
Flour, wheat	3	1:2	1500	8	2.2	38	.5
Check (untreated)	3		1500	719	4.6	500	48
Ashes, coal	3	1:4	1500	0		5	0
Ashes, wood	3	1:4	1500	32	2.4	28	2
Clay, Anderson	3	1:4	1500	0		146	0
Clay, Dawson	3	1:4	1500	0		47	0
Dutox	3	1:4	1500	0		346	0
Flour, wheat	3	1:4	1500	137	3.7	100	9.1
Lime, hydrated	3	1:4	1500	2	1.5	249	.1
Talc	3	1:4	1500	0		146	0
Check (untreated)	3		1500	686	3.5	224	43.7
Ashes, coal	3	1:10	1500	4	1.5	117	.2
Ashes, wood	3	1:10	1500	98	6	118	19.4
Clay, Anderson	3	1:10	1500	0		140	0
Clay, Dawson	3	1:10	1500	0		51	0
Dutox	3	1:10	1500	0		174	0
Flour, wheat	3	1:10	1500	127	2.2	105	8.4
Lime, hydrated	3	1:10	1500	2	1	274	.1
Talc	3	1:10	1500	0		103	0
Check (untreated)	3		1500	878	4.3	466	58.5
Ashes, coal	3	1:25	1500	6	1.8	206	.4
Ashes, wood	3	1:25	1500	10	1.1	128	.7
Clay, Anderson	3	1:25	1500	0		28	0
Clay, Dawson	3	1:25	1500	0		53	0
Dutox	3	1:25	1500	3	2	576	.2
Flour, wheat	3	1:25	1500	554	3	115	36.9
Lime, hydrated	3	1:25	1500	2	3.5	315	.1
Talc	3	1:25	1500	0		258	0
Check (untreated)	3		1500	845	3.6	280	56.3
Ashes, coal	3	1:50	1500	31	3.4	378	2
Ashes, wood	3	1:50	1500	63	2.6	767	8.2
Clay, Anderson	3	1:50	1500	1	1	65	.1
Clay, Dawson	3	1:50	1500	0		80	0
Dutox	3	1:50	1500	0		119	0
Flour, wheat	3	1:50	1500	287	1.5	140	19.1
Lime, hydrated	3	1:50	1500	1	1	165	.1
Talc	3	1:50	1500	0		161	0
Check (untreated)	3		1500	1023	4.3	267	68.2
Clay, Anderson	3	1:75	1500	0		59	0
Clay, Dawson	3	1:75	1500	2	1	87	.1
Dutox	3	1:75	1500	0		113	0
Lime, hydrated	3	1:75	1500	4	1.2	340	.3
Talc	3	1:75	1500	0		73	0

weevils were spread out on screen trays (two gallons per tray) above and below each tray containing the test materials so that the weevils developing there would have easy and uniform access to all bags. The

cabinet was placed in a room in which the temperature varied much as that of a common dwelling house, varying during this experiment from 61 to 101° F. The experiment was carried on for six months, May 1 to November 1, 1935. During this time the weevils in the cabinet passed through at least three complete life cycles.

The infestation counts were made just after the emergence of a generation of adults. The criteria used to determine whether the beans were infested were (1) the presence of exit holes in the beans and (2) the presence of holes which the larvae cut before they pupate. Several hundred beans with no external evidence of infestation were broken open and examined, but since so few larvae were found, it was decided that this rather laborous method of examination would add nothing to the validity of the tests.

Observations and results.—The individual checks (500 beans each) showed infestations ranging from 14 to 87 per cent. When the three replications were grouped as shown in table 1, the percentage of infestation ranged from 43.7 to 86.2 per cent. Fifty-four per cent of all the untreated beans were infested.

Dusting talc was the only material used which gave perfect protection at all dilutions. Anderson clay with exception of one infested bean at 1:50 dilution, Dawson clay with exception of two infested beans at 1:75 dilution, and *Dutox* with the exception of three infested beans at 1:25 dilution also gave perfect protection. Hydrated lime was nearly as efficient as the above, the final examination showing but two infested beans at 1:4 dilution, two at 1:10, two at 1:25, one at 1:50 and four at 1:75. The beans treated with coal ashes showed the following results: No infestation at 1:2 and 1:4 dilutions, four beans infested at 1:10, six at 1:25, and 31, or two per cent, at 1:50. The results with wood ashes were: No beans infested at 1:2 dilution, 32 beans infested at 1:4, 98 at 1:10, 10 at 1:25, and 63 at 1:50. The results with flour were: Eight beans infested at 1:2, 137 at 1:4, 127 at 1:10, 10 at 1:25, and 287, or 19.1 per cent, at 1:50.

If the number of dead weevils found in the bags can be considered a criterion of the repelling effect of the materials against the weevils, Dawson clay with 318 dead weevils in 15 bags was the most repellent and hydrated lime with 1343 dead weevils was the least repellent. The number of dead weevils per 15 bags of beans of each material was: Dawson clay 318, Anderson clay 438, flour 498, talc 741, coal ashes 755, wood ashes 1154, *Dutox* 1328, hydrated lime 1943, untreated material 1737.

The effectiveness of *Dutox* in protecting the beans can be ascribed to the fact that it poisons the adults and the young larvae. The other materials used were nonpoisonous. Their effectiveness was in direct proportion to their adhesivity to the beans. Flour, wood ashes and coal ashes adhered very poorly, only a trace of the material remaining on the beans after the dust was sifted off. On the other hand, Anderson clay, Dawson clay, hydrated lime and talc adhered very tightly to the beans. At dilutions of 1:50 and 1:75 of these materials practically all of the dust stuck to the beans. These dusts also wrinkled the seed coats and were rather difficult to remove in preparing the beans for cooking.

None of the dusts used seemed to impair the cooking quality or the taste of the beans. Since the coal ashes, wood ashes and flour did not adhere to the beans, the beans treated with them were much more easily prepared for cooking than those treated with the other dusts. Although *Dutox* seemed to have no injurious effects on the cooking qualities or taste of the beans, its poisonous nature makes it inadvisable for the protection of beans which are to be eaten.

None of the materials affected the germination of the beans.

Summary.—Untreated navy beans were 54 per cent infested by bean weevils when exposed to their attack for six months.

Anderson clay, Dawson clay, *Dutox* and dusting talc at all dilutions used gave perfect or nearly perfect protection to navy beans from infestation by the bean weevil.

Hydrated lime was a little less efficient than the foregoing materials but still very effective at all dilutions used.

Coal ashes prevented infestation at dilutions of 1:2 and 1:4 and allowed less than .5 per cent infestation at dilutions of 1:10 and 1:25.

Wood ashes gave perfect protection at dilutions of 1:2 but allowed an infestation of one per cent or more at greater dilutions.

Flour was ineffective at dilutions of greater than 1:2. It gave perfect protection at dilution of 1:1 in preliminary tests.

The protection afforded by the nonpoisonous dusts, especially at high dilutions, is definitely correlated with the adhesivity of the material.

None of the materials used affected the cooking quality or taste of the beans, but materials that adhered well and wrinkled the seed coat were much harder to remove by washing.

None of the materials used affected germination of the beans.

EXPERIMENTS WITH DERRIS AS A CONTROL FOR THE PEA APHID

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Control of the pea aphid, *Illinoia pisi* Kalt, in the large pea-canning areas of the central and eastern sections of the United States is difficult, because it usually involves the treatment of large acreages within a very short period of time before the rapidly multiplying aphids can cause serious damage to the crop. The method of control customarily recommended has been dusting with nicotine dust, but since its successful use depends upon the prevalence of high temperature, the absence of wind, and dry foliage, it has been difficult and often impossible for canners to dust all their pea acreage that needed dusting.

Plot tests with derris root during the 1935 season have given such promising results that it seems advisable to present them at this time. Three series of experiments were conducted: (1) In a greenhouse during the latter part of the winter and early in the spring, (2) in the field during

the normal pea-growing season, and (3) in the field late in the season on late-planted peas.

Experiments in the greenhouse.—Six preliminary tests were conducted with ground derris containing 3.7 per cent of rotenone and 16.1 per cent of total extractives (carbon tetrachloride method) at concentrations ranging from 1½ to 5 pounds per 100 gallons (.0066 to .022 per cent rotenone) and a pine-oil extract as a spreader and wetting agent at the rate of 1 part in 200. Potted pea vines supporting an average of 140 aphids each were sprayed with a small hand sprayer.

The mortality ranged from 92 to 100 per cent, averaging 98+ per cent for the six tests. The pine-oil extract when used alone at the same rate gave a mortality of only 5 per cent.

No appreciable difference could be observed in the performance of the various concentrations of derris, either in the time required to kill the aphids or in the final mortality. Two observations, however, appeared significant: All the aphids were not killed immediately, but they died over a period of five days, and practically no reproduction occurred in the interval between treatment and death.

Field experiments during the pea-growing season.—Many tests, on both small and large plots, were conducted during June and July on six acres of canning peas planted in rows. The variety was Perfection, a late sweet variety. Only one application was made to each plot. Generally the infestation was medium to heavy.[1]

Treatments were applied under various weather conditions. Temperature ranged from 68 to 88° F, relative humidity from 35 to 92 per cent, and wind velocity from 2 to 10 miles per hour.

The mortality following treatments was obtained by counting the dead and living aphids on the ground after thoroughly shaking the vines. The degree of reduction in the infestation following treatments was obtained by close observation.

Small-plot Tests.—The small plots consisted of a double row of peas 45 feet long. These two rows were six inches apart, and there was a space of two feet between one double row and the next. Seven tests were made on small plots, with four concentrations of ground derris containing 3.7 per cent rotenone and 16.1 per cent total extractives (carbon tetrachloride method). These concentrations, per 100 gallons, with their equivalents of rotonone, were approximately as follows: one-third pound (.0015 per cent), 1 pound (.0044 per cent), 3 pounds (.013 per cent), and 5 pounds (.022 per cent). The spreader and wetting agent, a commercial diphenyl butyl sodium sulfonate, was used at the rate of 1 part of a 40 per cent aqueous solution in 600 parts of water. Treatments were

[1] The relative degrees of infestation of the pea aphid on both row peas and broadcast peas, used at the Madison, Wis., laboratory, are as follows:

Degree of Infestation	Number of Aphids per Plant	Percentage of Plants Infested
None	0	0
Very light	1— 25	10
Light	26— 50	25
Light to medium	51—100	50
Medium	100—150	75
Medium to heavy	150—200	95
Heavy	200—300	100
Very heavy	More than 300	100

replicated four times. Sprays were applied with a knapsack sprayer at rates ranging from 150 to 235 gallons per acre and at pressures of from 100 to 125 pounds.

In the first test, conducted 10 days before the next test was possible because of rain, there was a definite indication that an application of

Table 1.—Vine condition and yields of peas in field plots treated with derris (3.7 per cent rotenone) and diphenyl butyl sodium sulfonate,* and in untreated plots, Waunakee, Wis. June–July 1935.

Test	Treated Plots				Check Plots				Ratio, Yield of Treated Plots to Yield of Check Plots	
	Condition of Vines†	No. of Plants per 10 Feet	Yield of Peas		Condition of Vines	No. of Plants per 10 Feet	Yield of Peas		On Area Basis	On Basis of Equal Number of Plants
			Ounces per 10 Feet	*Ounces per 113 Plants*			*Ounces per 10 Feet*	*Ounces per 113 Plants*		
					Small Plots					
1	G+	108	10.5	11	P	134	6.19	5.2	1.7:1	2.11:1
	G+	106	13.06	13.9	M+	154	12	8.8	1.09:1	1.58:1
	M+	90	9.56	12	M−	105	3.75	4.05	2.55:1	2.96:1
	G	114	11.56	11.45	P	125	8.25	7.45	1.4:1	1.54:1
Average	*G*	*104.5*	*11.17*	*12.09*	*M−*	*129.5*	*7.55*	*6.37*	*1.48:1*	*1.9:1*
2	G+	113	16.87	16.87	M	110	6.62	6.8	2.55:1	2.48:1
	M+	99	12.62	14.4	M	97	7.44	8.65	1.7:1	1.66:1
	G+	123	17.37	15.7	P−	133	2.06	1.75	8.44:1	8.98:1
	G+	83	12	16.35	P	134	6.19	5.2	1.94:1	3.15:1
Average	*G+*	*105*	*14.72*	*15.83*	*M−*	*118.5*	*5.58*	*5.6*	*2.64:1*	*2.83:1*
					Large Plots					
3	G+	103	7.44	8.15	P−	147	2.69	2.07	2.77:1	3.94:1
	G	84	7.12	9.6	P−	133	2.06	1.75	3.46:1	5.5:1
	G	104	11.69	12.1	P	134	6.19	5.20	1.89:1	2.33:1
Average	*G*	*97*	*8.75*	*9.95*	*P−*	*138*	*3.65*	*3.01*	*2.4:1*	*3.3:1*
4	G	122	20.25	18.8	M−	113	4.37	4.37	4.63:1	4.31:1
	G+	139	13.87	11.3	P	111	5.94	6.05	2.34:1	1.87:1
	G+	139	15	12.2	M	126	14.25	12.8	1.05:1	.954:1
	G	138	19.44	15.9	P	128	7.87	6.95	2.47:1	2.29:1
Average	*G to G+*	*134.5*	*17.14*	*14.55*	*M−*	*119.5*	*8.11*	*7.54*	*2.12:1*	*1.93:1*
5	M+	163	16.93	11.75	M−	158	11.17	8	1.52:1	1.47:1
	G	124	14.07	12.93	M−	157	6.33	4.57	2.23:1	2.83:1
	G	154	13.62	9.97	P	171	8.04	5.26	1.7:1	1.9:1
Average	*G*	*147*	*14.87*	*11.55*	*M−*	*162*	*8.51*	*5.94*	*1.75:1*	*1.95:1*
6	G	168	19.4	12.96	M+	138	13.6	9.14	1.43:1	1.42:1
	G	187	20.6	12.46	M−	159	11.2	7.98	1.84:1	1.56:1
	G	190	17.37	10.3	P	162	13.4	9.22	1.3:1	1.12:1
Average	*G*	*181.5*	*19.12*	*11.91*	*M−*	*159.5*	*12.73*	*8.78*	*1.5:1*	*1.36:1*
General average	*G*	*126*	*14.3*	*12.86*	*M−*	*136.5*	*7.6*	*6.25*	*1.88:1*	*2.06:1*

* In all tests except No. 3, the concentration of derris was 3 pounds to 100 gallons of water (.013 per cent rotenone) and that of the spreader 1:600; in test 3 the concentration was three-fourths pound of derris (.0033 per cent rotenone) per 100 gallons and the spreader was used at the rate of 1:200.

† G+, very good; G, good; M+, good to medium; M, medium; M−, medium to poor; P, poor; P−, very poor.

derris, after killing practically all the aphids in a few days, kept the vines from becoming reinfested for more than two weeks. The treated plots were surrounded by large untreated, heavily infested areas, which were damage by the aphid to such a degree that no crop was harvested, and in which large numbers of aphids were continually crawling over the ground. With constant opportunity for reinfestation, however, the treated plots remained practically free of infestation for the period stated.

Six later treatments did not result in such rapid reduction of the aphid

population. Frequently not more than 40 to 75 per cent of the aphids could be found dead after 24 hours, but they continued to die throughout a period of three, four or five days, depending upon weather conditions. As in the greenhouse tests, it was observed that there was little reproduction, and sometimes none whatever, among mature aphids before death.

In four of the six tests the mortality of aphids for the four replicated plots averaged from 87 to 97 per cent, with an average of 93 per cent for the series. In the other two tests mortality records were interrupted by heavy rains shortly after treatment, but in one case an average mortality of 45 per cent was noted after four hours and in the other 81 per cent after 16 hours.

No differences could be discerned in the percentages of aphids killed with the various concentrations of derris. The lowest concentration showed an average mortality of 94 per cent for the four plots.

The diphenyl butyl sodium sulfonate spreader and wetting agent, when used alone on replicated plots at the same concentration (1–600) as in the tests with derris, killed 24 per cent of the aphids. When used alone at concentrations of 1:200 and 1:100, it killed 75 per cent and 72 per cent, respectively.

Another test was made with 1 part of ground derris to 3 parts of a bentonite carrier (.925 per cent rotenone). The mixture was applied to four plots with a knapsack duster without a trailer. (A small trailer was used in most of the hand-dusting tests.) The aphid mortality averaged 69 per cent after several days.

Large-plot Tests.—The large plots were approximately one-fourth or one-half acre in size, and two plots were treated in each test. The material was applied with a power sprayer arranged to treat three rows at a time with three nozzles to the row. From 112 to 134 gallons per acre were applied in the different tests at a pressure of approximately 300 pounds. Four tests were made with a single application, three tests with derris (3.7 per cent rotenone) at a concentration of 3 pounds to 100 gallons (.0133 per cent rotenone) and spreader at the rate of 1:600, and 1 test at three-fourths pound of derris to 100 gallons (.0033 per cent rotenone) and spreader at the rate of 1:200.

The results were comparable with those of the small-plot tests. The average mortality was from 90 to 95 per cent, averaging 94 per cent for all four tests.

Condition of Vines and Yields of Peas.—Just before the different plantings of peas were ready for harvest, certain of the small and large plots were selected for hand sampling. Careful notation was made regarding the appearance of vines and the set of pods, and the plots were rated in seven categories from very good to very poor.

At harvest time small samples were taken at random from these plots. In the small plots samples were taken from each of the four replicated plots, while in the large plots the samples were taken from three or four parts of the two replicated plots. In these samples the plants were counted, the pods were picked off and shelled by hand, and the peas were weighed. Table 1 gives a summary of the results. The weight of

shelled peas is shown on the basis of both area (10-foot strip) and an equal number of plants for all treated and check plots. The weight on the area basis is the actual weight of peas harvested according to the stand of plants and the presence of pods, while the weight per equal number of plants is shown to facilitate comparisons between treated and check plots. The treated and check plots harvested were adjacent to each other in every case but one.

Of the 21 ratings of vine condition, all but three were good or very good. The average ratings for the groups of plots in all six tests were good or very good. In the check plots none of the ratings were above medium, and the average ratings for the six groups were medium-to-poor or very poor.

Two samples failed to exhibit an appreciable favorable yield ratio by each method of rating, and one of these samples gave an unfavorable ratio by both methods of rating. The average ratios for the entire experiment show that the treated samples outyielded all check samples, the increase being 88 per cent on an area basis and 106 per cent on the basis of an equal number of plants.

Field experiments on late-planted peas.—In an effort to follow up quickly the promising lead obtained with ground derris during the regular season, one-fourth acre of peas was planted late in July. The peas were of the same variety used earlier in the season, but the field was sowed broadcast instead of in rows. Three principal groups of tests were made: (1) Before infestation, (2) with a light infestation, and (3) with a heavy infestation.

One application was made with a knapsack sprayer or duster to plots approximately 150 square feet in size. The plots were not replicated, but the applications were made progressively from day to day, and the quantity of spray or dust was varied in such manner as to obtain light and heavy applications.[2] Treatments were applied under varied weather conditions, the temperature ranging from 49 to 87° F and the wind velocity from 2 to 10 miles per hour.

The materials and their concentrations, unless otherwise noted, were as follows: For the sprays, ground derris root (3.2 per cent rotenone and 13 per cent total extractives by the carbon tetrachloride method) 3 pounds, a diphenyl butyl sodium sulfonate (40 per cent aqueous solution) 1:600, water 100 gallons. The rotenone content of the final spray mixture was .012 per cent. For the dusts, ground derris root of the same rotenone and total extractives content 1 pound, New Jersey kaolin-type clay or Georgia kaolin 7 pounds. The rotenone content of the dust was .4 per cent.

All tests were concluded during the latter part of September immediately prior to a killing frost.

Tests Prior to Aphid Infestation.—The first tests were made in the middle of August, when the peas were about 4 inches high, and before any aphids were present. One plot was dusted, one was given a light ap-

[2] Calculated on the basis of quantities of spray or dust actually applied to the small plots involved in these tests, a light application of spray ranged from approximately 150 to 200 gallons per acre and a heavy application from approximately 250 to 350 gallons; a light application of dust ranged from approximately 50 to 90 pounds per acre and a heavy application from 125 to 140 pounds.

plication and one a heavy application of spray, and two plots were left untreated as checks.

Ten days after treatment there were no aphids on the two sprayed plots. There were a few on the dusted plot and a few more on the checks than on the dusted plot. A month after treatment the infestation of the two sprayed plots was very light, that of the dusted plot light, and those of the check plots light and medium-to-heavy. The foliage of the sprayed plots was decidedly better in appearance than that of any of the other plots.

The infestation increased rapidly in all plots during the latter part of September, so that 43 days after treatment the sprayed plots were uniformly infested, but not so heavily as were the other three plots. The heavily sprayed plot, moreover, had fewer aphids and better appearing vines than the lightly sprayed plot.

Tests with Light Infestations.—On August 22, 26 and 30 seven plots were given light or heavy applications of derris dust, six plots were given light or heavy applications of derris spray, and six plots interspersed with the treated ones were left as checks.

At the time of treatment the infestations in the different plots ranged from very light to light. In fact the infestation was generally so light that no effort was made to determine the percentage of aphids killed, but observations were confined to determining the freedom of the vines from infestation for several weeks after treatment.

During the last of September, from 37 to 29 days after treatment, the seven dusted plots had infestations varying from medium to very heavy. The condition of the vines varied from medium-to-poor to very poor. The dust had delayed the increase of aphid populations temporarily. In general, the dusted plots did not become so heavily infested as the check plots, and the condition of the vines was slightly better.

At the close of the tests the six sprayed plots had infestations varying from very light to medium-to-heavy. The condition of the vines varied from very good to medium-to-poor. The infestation was controlled much better in these plots, and for a longer period, than in the dusted plots. The pea aphid infestation in the sprayed plots was controlled for nearly a month to such a degree that a profitable crop was produced.

The six check plots became uniformly infested soon after the tests were begun, and at the end of the tests the infestation was heavy or very heavy. The vine condition was poor or very poor. The plants in some of the check plots were dead, while others still had green foliage but had not developed pods.

Tests with Heavy Infestations.—Between September 6 and 24 tests were made with heavy infestations of aphids. It will be necessary to discuss these tests in groups, since the rapidly increasing infestation and injury to pea vines frequently changed the conditions under which the tests were conducted.

On September 6, 9 and 17, two plots were given heavy applications of derris dust and two were given heavy applications of derris spray. The infestation was medium to very heavy. On September 25 the two dusted plots had very light and light infestations and the vine condition rated

good-to-medium and very good, respectively. The two sprayed plots had very light infestations, and the vine condition rated good and very good. Of seven check plots, four had very heavy infestations, the vines rating very poor, while three had medium-to-heavy infestations, the vines rating medium to medium-to-poor.

On September 19 two heavy applications of dust and three of spray were made to heavily infested plots which exhibited severe injury by the aphid at the time of treatment. Six days later the infestation in the dusted plots was very light and light-to-medium, while in the sprayed plots a very light infestation prevailed. Five check plots had very heavy infestations. The rating of vine condition was no longer significant because of the severe injury before the treatment.

An additional test with a heavy application of derris without any spreader and wetting agent on a heavily infested plot gave a satisfactory reduction of the infestation, but the reduction was slower and not so great as in the plots where the spreader and wetting agent was used.

Four other tests were also made on September 19, using derris with two different spreaders and wetting agents, sodium lauryl sulfate (a powder), 9 ounces per 100 gallons, and a sodium oleyl sulfate (a liquid), 1 part in 600. In all cases the heavy infestation was reduced satisfactorily.

On September 21 and 24 heavy applications of dust or spray were made in 19 tests on medium to very heavily infested vines. The percentage of aphids killed as a result of the treatments was determined after two to four days. It was not feasible to await the reduction in infestation which it was anticipated would be apparent in a week, because of the severe pea aphid injury that had been sustained by the vines and because a killing frost was expected daily.

Four tests were made with derris dust. In one test the pea vines were sprayed with water just before the dust was applied. The aphid mortality in these tests ranged from 50 to 65 per cent. No benefit was obtained from the water spray. Observations over a longer period probably might have shown higher mortality.

Three tests with derris spray resulted in mortalities of 90, 95 and 95 per cent, respectively.

Two tests with derris, one-half pound to 100 gallons (.0019 per cent rotenone) but without a spreader and wetting agent resulted in mortalities of 80 and 75 per cent. This material killed the aphids more slowly than when a spreader and wetting agent was used. Two tests with derris one-half pound to 100 gallons and two with derris, one-fourth pound to 100 gallons (.0009 per cent rotenone), using sodium lauryl sulfate, 9 ounces per 100 gallons and sodium oleyl sulfate 1:600 as spreaders and wetting agents with each concentration of derris, resulted in mortalities ranging from 90 to 95 per cent, with an average of 94 per cent for the four tests.

These two spreaders and wetting agents used alone at the same concentrations killed from 15 to 25 per cent of the aphids present, with an average of 20 per cent for the four tests. The diphenyl butyl sodium sulfonate used alone at 1:600 in two tests killed 15 and 6 per cent of the aphids.

In the seven check plots in this series of tests the plants were heavily infested by aphids. The aphid mortality ranged from 2 to 5 per cent per plot, with an average of 3 per cent.

Summary and conclusion.—The greenhouse tests demonstrated that ground derris as a spray, applied at the rate of from 1½ to 5 pounds per 100 gallons of water (.006 to .022 per cent rotenone), with a spreader and wetting agent, killed nearly 100 per cent of the aphids on the treated plants. The aphids died throughout a period of from three to five days, and practically no reproduction occurred in the interim.

Many summer field tests, on both small and large plots, demonstrated that ground derris as a spray, applied at the rate of from one-fourth pound to 5 pounds per 100 gallons (.0009 to .022 per cent rotenone), with a spreader and wetting agent, killed more than 90 per cent of the aphids on the treated plants, that from three to five days were required to obtain the maximum mortality, and that little or no reproduction occurred during that period. These tests further revealed that the application of derris sprays increased the yield of shelled peas approximately 88 per cent over that of untreated checks.

A large number of tests on late-planted peas revealed that derris as a spray, with a spreader and wetting agent, applied prior to aphid infestation protected the plants from appreciable damage for several weeks and resulted in an ultimate infestation considerably lower than had developed in the untreated checks; that heavy applications of derris sprays after the incidence of an infestation protected peas from damage from a commercial standpoint for nearly a month, enabling them to produce a normal crop of pods; that heavy applications of derris sprays with any one of several spreaders and wetting agents, made after the infestation had become heavy, killed approximately 95 per cent of the aphids; that derris sprays controlled the aphid more quickly and to a higher degree than did derris dusts; and that concentrations of derris as low as one-fourth to one-half pound (.0009 to .0019 per cent rotenone) per 100 gallons, with spreaders and wetting agents, killed approximately as large a percentage of aphids as did 3 pounds per 100 gallons.

On the basis of the experiments reported herein, it appears that sprays of ground derris root containing .0044 per cent rotenone, or possibly lesser concentrations, with a spreader and wetting agent, applied to pea vines while aphids are present in small numbers, give promise of effective control of the pea aphid.

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IN MAY 1936, a meeting was held at the Rothamsted experiment station to discuss the possibility of starting a cooperative insurance scheme between beekeepers' associations, under which the members would receive compensation for losses incurred through the incidence of foulbrood. It is stated that a plan of insurance along these lines is in operation in Switzerland. Among other things, the proposals involved an annual premium, collectible from members; compensation to be paid on a sliding scale, taking into account the time of the year for bees and the age and quality for combs; no compensation to be paid if the disease is not reported until the entire stock is dead; the insurance of hives and appliances.

EFFECTS OF SOME INORGANIC SALTS ON DEVELOPMENT AND REPRODUCTION OF THE BEAN WEEVIL

ACANTHOSCELIDES[1] *OBTECTUS*

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While studying development of the bean weevil, *Acanthoscelides obtectus*, the author noted different rates of development of this insect when reared in different varieties of beans. Since McHargue & Roy (*7*) have shown that the mineral content of beans depends on the variety and on its stage of development, it seemed desirable to attempt an analysis of the effects of some inorganic salts on the development and the reproduction of the bean weevil by adding varying amounts of a single salt to the normal food. Headlee (*5*) noted that certain chemicals might have an accelerating or retarding influence on the rate of the development of the bean weevil. This conclusion was arrived at indirectly when he was studying the effects of relative humidity on the development of this insect by using saturated solutions of various salts through which to draw the air and thus obtain the desired humidity. Breitenbecker (*1*) noted that acids and bases have a modifying effect on the rate of development of the cowpea weevil.

The role of inorganic salts in the nutrition and metabolism of insects has not been extensively studied. Uvarov (*8*) has reviewed the literature on this subject. Cavazza (*2*, *3*) fed silkworms on mulberry leaves that had been sprayed with different chemicals and noted the effects on size, weight, and reproductivity of the adults. According to Uvarov (*8*), Reznitschenko (1927) found that potassium chloride and calcium chloride added to the normal food do not retard the development of *Drosophila melanogaster* except at high concentrations.

Materials and methods.—White navy beans were used as food for the developing bean weevil larvae. The beans were split in half between cotyledons so as to break the seed coat, allowing for better penetration by the salt solutions and at the same time facilitating the entrance of the young larvae.

From preliminary experiments it was noted that the amount of any salt added to the normal food determines the extent of its effect on the bean weevil; too high a concentration proves to be lethal. A series of concentrations—concentrated enough to affect the development but not to kill all the bean weevils—of each salt was selected. The concentrations and the amount of each salt solution added to each 25-gram lot of beans is shown in table 1. One control was treated with 12 cubic centimeters of distilled water and the other was untreated.

The treated beans were allowed to stand overnight and were then dried to their original weights in an oven maintained at about 50° C.

[1] **Bridwell, J. C.** 1920. Proc. Ent. Soc. Wash. 31:42.

[2] The author desires to acknowledge his indebtedness to Professor Wm. S. Marshall for kindly criticisms and suggestions.

Twenty adult bean weevils 1 day old were put in each lot of beans and the females allowed to oviposit for a period of five days, after which the beetles were removed and the eggs counted. During the oviposition period and during the period of the development of the progeny, the cultures were kept in a chamber whose temperature was maintained at an approximate average of 30° C.

As the progeny matured some of them were removed on the day of emergence and weighed in groups of 10 to 30 and the average taken as the weight of one individual. After weighing, these beetles were killed with chloroform and dried to constant weight in an oven maintained at about 75° C. Some of the adult progeny were removed on the day of maturity to beans treated exactly the same way as the beans in which they had been reared. The females were allowed to deposit all of their eggs and from these a second generation was reared at an average temperature of 25° C. The humidity in any case was not controlled.

Table 1.—Amounts of salt solutions added to 25 grams of white navy beans.

No.	Treatment of Beans	Amount of Solution cc.	Molar Concentration
1	Control	12	
2	Distilled water control	12	
3	Calcium chloride	12	.01
4	Sodium chloride	12	.01
5	Sodium nitrate	12	.01
6	Sodium sulfate	12	.008
7	Potassium chloride	12	.01
8	Ferric sulfate	12	.002
9	Ammonium chloride	12	.01

Results.—There appears to be an inhibiting influence on the oviposition of the bean weevil by potassium chloride and sodium sulfate when the ovipositing females had been reared in normal beans. The other salts used have slight or no influence on oviposition.

The percentage of mortality was determined from the original number of eggs and the number of progeny maturing. In the controls the percentage of mortality of the larvae was 12.1 per cent, in $CaCl_2$-treated beans 22 per cent, in NaCl and $NaNo_3$-treated beans 26 per cent, in Na_2So_4-treated beans 35.4 per cent, in $Fe_2(SO_4)_3$-treated beans 34 per cent, and in KCl-treated beans 45 per cent.

Death of the young larvae before or soon after having entered the treated beans accounted for most of the mortality, except in the case of sodium sulfate-treated beans where a large number of individuals died soon after having attained the pupal condition.

At 30° C the number of days required for complete development of the bean weevil in the controls was 34 to 43 days. In the beans treated with specified amounts of NaCl, $NaNO_3$, $NaSO_4$ and KCl, development required two to eight days more. This group of salts prolongs the larval, prepupal and pupal stages. Treatment of the beans with ferric sulfate delays the development of the bean weevil by two or three days, but only the larval stage is prolonged. Calcium chloride and ammonium chloride, in the amounts used here, do not affect the rate of development.

The second generation, reared in beans treated in the same way as for the first generation, took a longer period to complete their development because they were reared at the lower temperature of 25° C. The same salts that lengthen the developmental period at 30° C also lengthen it at 25° C. At the latter temperature the controls developed in from 42 to 52 days, the same as those developing in ammonium or calcium chloride-treated beans. Those reared in beans treated with sodium chloride, sodium nitrate, sodium sulfate or potassium chloride required four to seven days longer to complete their development. Ferric sulfate lengthened the period of development of the bean weevil by two days.

Table 2 shows the weights of the newly matured adults when they were reared at an average temperature of 30° C in beans treated with different salts. When larvae are reared in beans treated with calcium chloride or ferric sulfate the resulting adults are heavier than the controls in both average live and dry weights. Beetles reared in beans treated with ammonium chloride are lighter than the controls in live weights but are heavier in dry weights because of the much lower percentage of moisture contained. Bean weevils reared in beans treated with sodium nitrate or sodium chloride are lighter than the controls in both average live and dry weights. Complete data were not obtained for beetles reared in beans treated with potassium chloride or sodium sulfate. The one set of dry weights obtained for potassium chloride indicates that it affects the weight of the bean weevil in about the same manner as does sodium chloride. Sodium sulfate does not appear to affect significantly the dry weights of beetles reared in beans treated with it.

Table 2.—Effects of various salts on the weight of newly emerged adult *A. obtectus* when reared at an average temperature of 30° C.

Treatment of Beans	Av. Live Weight	Av. Dry Weight	Per Cent Water	No Weighed
	mg.	*mg.*		
Control	5.88	2	66	81
Distilled water control	5.72	1.95	65.9	90
Calcium chloride	6.84	2.64	61.4	38
Sodium chloride	5.40	1.75	67.6	40
Sodium nitrate	5	1.77	64.6	36
Sodium sulfate		2.16		42
Potassium chloride		1.65		34
Ferric sulfate	7.06	2.39	66.2	17
Ammonium chloride	5	2.28	54.4	30

Some of the beetles reared at 30° C in beans treated with the various salts were removed from the cultures and allowed to oviposit on beans treated in exactly the same manner as those upon which they had been reared. Table 3 shows the number of females ovipositing and the number of offspring developing in each case. This second generation was reared at an average temperature of 25° C. The average number of offspring per female is much larger than the average per female of the control groups when the beetles had been reared in beans treated with calcium chloride or ammonium chloride. Ferric sulfate was found not to affect significantly the reproductivity of the bean weevil. Sodium chloride, sodium nitrate,

sodium sulfate and potassium chloride all affected the reproductivity of the beetles reared in beans treated with them by reducing the number of offspring that are capable of developing to maturity. Potassium chloride caused the greatest reduction. The relative fecundity as calculated from the average number of offspring per female (assuming that the control represents 100 per cent) is shown in the last column of table 3. By comparing the relative fecundity with the average dry weights of the newly matured adults there appears to be some correlation between the dry weights at maturity and the relative fecundity of the beetles. Thus, beetles reared in beans treated with calcium chloride or ammonium chloride have a higher average dry weight and a higher relative fecundity, as compared with the controls. Beetles reared in beans treated with ferric sulfate have a higher average dry weight but are not appreciably different from the controls in relative fecundity. Beetles reared in beans treated with NaCl or KCl are 12.5 and 17.5 per cent lighter than the

Table 3.—Development at 25° C of the second generation of *A. obtectus* reared in beans treated as outlined in table 1.

Treatment of Beans	No. Females Ovipositing	No. Offspring	Offspring per Female	Relative Fecundity *Per Cent*
Control	17	589	34.65	100
Distilled water control	15	450	30	86.6
Calcium chloride	11	531	48.3	139.4
Sodium chloride	20	91	4.55	13.1
Sodium nitrate	23	183	8	25.9
Sodium sulfate	8	23	2.9	8.4
Potassium chloride	14	9	.64	1.8
Ferric sulfate	8	256	32	92.3
Ammonium chloride	12	505	42	121.2

controls in average dry weights and their reproductivity is most markedly lowered. Sodium nitrate affects the reproductivity and the weight of the bean weevil about the same as does NaCl. Sodium sulfate does not affect greatly the dry weights of the adults but the fecundity is much lowered.

A few late pupae developing at 30° C in the control beans and in beans treated with $CaCl_2$, $NaNO_3$ and $Fe_2(SO_4)_3$ were transferred to untreated beans, and the females, when mature, allowed to oviposit. The results are shown in table 4. Although the number of females was small, the results offer a corroboration for the high relative fecundity shown in table 3 for those beetles reared in beans treated with $CaCl_2$. The average number of eggs laid by females reared in $CaCl_2$-treated beans is greater than for control females and the eggs of the former group are more viable. The eggs laid by females reared in beans treated with ferric sulfate are reduced in viability, but the average number per female is greater than the average for the control females. Beetles reared in beans treated with $NaNO_3$ laid as many eggs as the controls but only one-half of them hatched, the remainder collapsing soon after being deposited.

In another series of experiments, beans were treated with one-third the quantities of KCl, NaCl or $CaCl_2$ as was used in the first series. The rates of development of the bean weevils at 25° C in beans treated with

any of the three salts in this quantity were not appreciably different from the controls. The smaller quantity of potassium chloride was less toxic to the young larvae. Beetles reared in beans treated with NaCl or KCl were lighter than the controls in dry weights even at this lower concentration. Those reared in beans treated with the smaller amount of $CaCl_2$ were not appreciably different in weights from the controls.

Discussion and conclusions.—Ferric sulfate in sufficient amounts increases the duration of the larval stage of the bean weevil. Cavazza (*2*) found that ferrous sulfate increases the duration of the larval stage of *Bombyx mori*. Sodium chloride, $NaNO_3$ and KCl in the larger quantities affects the development of *A. obtectus* by increasing the duration of the larval, prepupal and pupal stages. This effect is apparent whether the beetles are reared at 25 or 30° C, but the differences in developmental rates are greater at the lower temperature. Cavazza (*2*), for the quantities which he used, found that potassium chloride does not affect the

Table 4.—Oviposition of *A. obtectus* reared at 30° C in beans treated with various salts. Development of the progeny reared at 25° C in untreated beans.

	Control	Distilled Water Control	Calcium Chloride	Sodium Nitrate	Ferric Sulfate
No. females ovipositing	3	2	2	4	3
Total eggs laid	99	54	84	125	124
Av. no. eggs per female	33	27	42	31	41
Total adult progeny	58	28	67	65	42
Percentage developing	58.6	52	80	52	42
No. days for development	42–50	42–51	42–48	42–51	42–47

rate of development of the silkworm. From preliminary investigation, sodium chloride seems to decrease the rate of water loss by the bean weevil during the prepupal and pupal stages.

The effect of the sodium salts of the weights of bean weevils depends upon whether they contain monovalent or divalent anions. Although sodium sulfate is relatively toxic to the bean weevil, individuals reared in beans treated with it are not appreciably different from the controls in average dry weights. Beetles reared at 30° C in beans treated with NaCl or $NaNO_3$ are lighter than the controls both in average live and average dry weights; potassium chloride apparently affects the weights of the bean weevil in a similar manner. It would appear that monovalent salts, excepting NH_4Cl, influence and increase in metabolism during the developmental stages. Cavazza (*2*) observed that KCl influences a decrease in weight of the silkworm. Hess (*6*) found that KCl increases the respiratory rate of *Planaria dorotocephala* while NaCl does not affect respiration except through the stimulating action on the musculature of the animals.

Bean weevils reared at 30° C in beans treated with ferric sulfate are heavier than the controls in both average live and average dry weights. According to Uvarov (*8*), Linden (1899) found that ferrous albuminate has a stimulating effect on the growth of the larvae of *Vanessa urticae* and the resulting adults are large. Cavazza (*2*) found that ferrous sulfate causes a reduction in weights of silkworms but the resulting adults are

heavier than the controls, due to a reduction in the loss of weight during pupation. A possible explanation of the effect of ferric sulfate and calcium chloride on the weight of the bean weevil may be in the effects of these salts on respiration. Fink (*4*) found that ferric and calcium oxides decrease the rate of respiration of adult potato beetles.

It was shown that those salts which cause a decrease in weights of the young adult bean weevils also cause a decrease in the number of offspring obtained from these beetles. Cavazza (*2*) found the KCl causes the females of *Bombyx mori* to lay fewer eggs which are lighter in weight than those of the controls. Bean weevils reared at 30° C in beans treated with $CaCl_2$ produced the largest number of offspring and are the heaviest adults at the time of their maturity.

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FUMIGATION OF FLOUR MILLS WITH HYDROCYANIC ACID GAS

R. T. Cotton, H. D. Young and George B. Wagner, *U.S.D.A., Bureau of Entomology and Plant Quarantine*

Hydrocyanic acid gas is more generally used in the United States as a flour-mill fumigant than any other chemical, and when properly applied can be depended upon to give a kill of mill insects closely approximating 100 per cent.

During the last two seasons the writers have observed many mill fumigations in the middle western area with the result that they have accumulated a considerable quantity of data relative to the efficiency of these fumigations as affected by the methods of producing and applying the gas, the type of construction of the building, the preparation of the mill, wind velocity, etc. A few of the observations are discussed in this paper.

Observations were made as to the relative cost and as to the efficiency of the fumigations in terms of insects killed and in gas concentrations obtained.

To determine the gas concentrations present in the mills while under fumigation, samples of air were taken from various parts of the mills at regular intervals throughout the periods of exposure. For purposes of

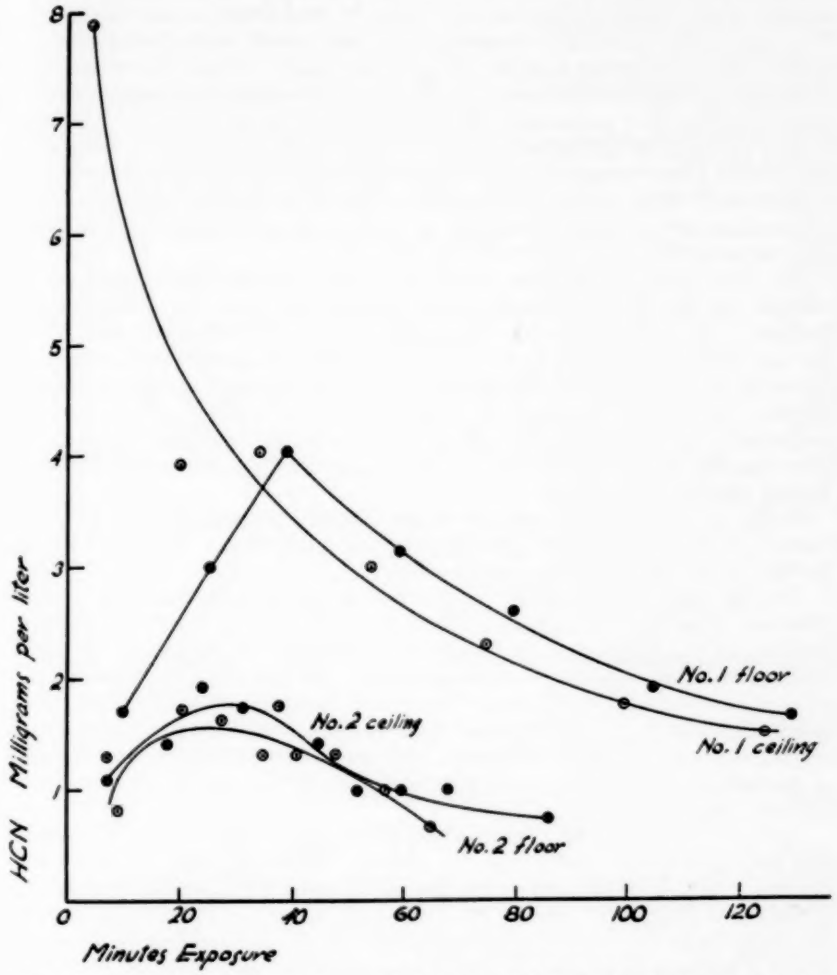

Fig. 1.—Gas concentration in flour mills Nos. 1 and 2 during fumigation with hydrocyanic acid. Mill No. 1 fumigated by pot method, dosage 7.6 ounces HCN per 1000 cubic feet. Mill No. 2 fumigated by liquid method, dosage 11.25 ounces per 1000 cubic feet.

comparison samples were taken for the most part from similar locations in each mill.

Quarter-inch or three-eighths-inch copper tubing, leading from the various locations chosen in the mill to a place on the outside, was utilized

to obtain the air samples. Before taking the samples sufficient air was withdrawn to compensate for the volume of the tube. The hydrocyanic acid content of the air was determined from time to time by aspirating 1 liter of air through a 1 per cent solution of sodium carbonate to which a crystal of potassium iodide had been added. The solution was titrated at once with a N/100 silver nitrate solution and results calculated as milligrams of hydrocyanic acid per liter of air space. A concentration of 1 milligram of hydrocyanic acid per liter is approximately equivalent to a concentration of 1 ounce per 1000 cubic feet of space.

It is customary to fumigate flour mills with hydrocyanic acid gas by introducing the fumigant into the open mill space either by forcing liquid hydrocyanic acid through a system of pipes and spray nozzles or by generating the gas from a mixture of sodium cyanide and dilute sulfuric acid in generators distributed over the mill.

The first method, referred to in this paper as the liquid method, is usually employed by professional fumigators, whereas the second or pot method is more often practiced by millers who wish to do their own fumigating. The greater skill in preparing a mill for fumigation exercised by the crew of a professional fumigator often lends the appearance of greater effectiveness to the method of using liquid hydrocyanic acid. Observations indicate, however, that the pot method can be depended upon to give equally good results if the proper preparations are made and sufficient chemicals used.

In figs. 1–3 are shown curves representing the concentrations of hydrocyanic acid found in flour mills during their fumigation, some by the pot method and others by the liquid method.

The gas generated by the pot method is hot and its behavior is well illustrated by the two upper curves of fig. 1, which represent the concentrations of hydrocyanic acid found near the floor and ceiling of the third floor of mill No. 1 during its fumigation by the pot method. The hot gas at first rises rapidly to the top of the room in which it is generated, then gradually falls as it cools, so that the gas concentrations at the floor and ceiling reach a point of equilibrium in from 30 to 40 minutes after the gas is generated and remain practically uniform throughout the remainder of the exposure.

Gas produced by the vaporization of liquid hydrocyanic acid is cold and acts in a different manner. Its action is illustrated by the two lower curves of fig. 1, which represent the gas concentrations found near the ceiling and floor of the second floor of mill No. 2 during its fumigation by the liquid method. The gas concentrations at top and bottom of the room reach a state of equilibrium almost immediately and remain fairly uniform throughout the fumigation.

The effect of wind velocity on the distribution of hydrocyanic acid gas in a mill is quite marked, particularly in mills that are loosely constructed. This effect is demonstrated by the two lower curves of fig. 1. These curves represent gas concentrations on the windward side of mill No. 2 when the wind was blowing at the rate of 23 miles per hour. The mill was a wooden frame building covered with sheet metal and not very tight. Although a dosage of 11.25 ounces of liquid hydrocyanic acid per

1000 cubic feet of space was applied, the maximum concentrations obtained on this side were less than half those obtained in the fumigation of mill No. 1, in which a dosage of only 7.6 ounces was used. Mill No. 1 was of stone and frame construction and was protected from the force of the wind by a nearby warehouse.

The curves of fig. 2 represent gas concentrations obtained during the fumigation of mill No. 3 by the pot method. The mill was of wooden frame construction covered with sheet metal, a type of construction typical of many flour mills in the middle west.

Two hundred forty-four pounds of sodium cyanide distributed in 80 earthenware crocks furnished the equivalent of a dosage of 8.2 ounces of hydrocyanic acid per 100 cubic feet for the 237,905 cubic-foot content

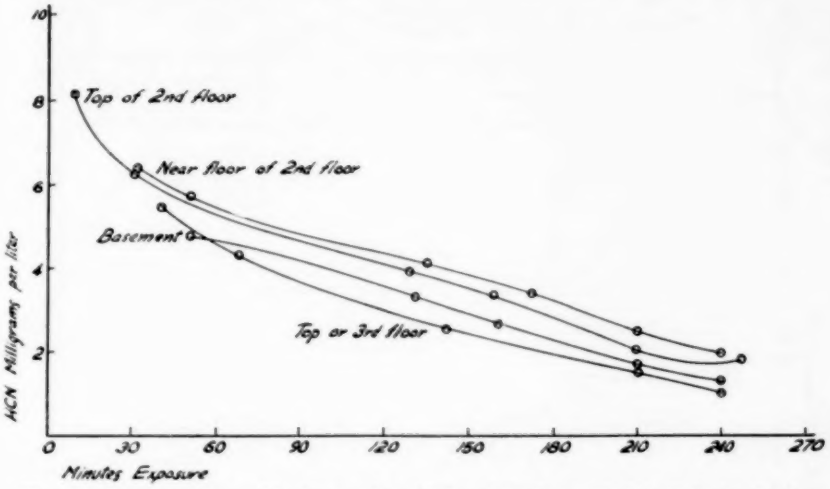

Fig. 2.—Concentrations of hydrocyanic acid found in flour mill No. 3 during fumigation by the pot method. Dosage 8.2 ounces HCN per 1000 cubic feet.

of the mill. The generators were divided as equally as possible between the basement and the three floors of the mill.

It is evident from a study of these curves that hydrocyanic acid gas does not stratify or become concentrated in any one part of a mill, but tends to become uniformly distributed. Gas samples taken from locations near the floor and ceiling of the second floor of the mill over a period of four hours show that a state of equilibrium was reached in about 30 minutes and maintained throughout the rest of the period.

Although hydrocyanic acid gas is slightly lighter than air it does not tend to concentrate on the upper floors of a mill. It will be noted from the concentration curves of fig. 2 that during the last three of the four hours of fumigation when gas samples were taken the concentration of gas was actually lower on the top floor than on the basement or second floors. A similar behavior of the gas has been observed in many mill fumigations. The same thing is again demonstrated by the gas concentration curves of

fig. 3. In many of the older bulletins on mill fumigation statements are made to the effect that hydrocyanic acid gas, being lighter than air, concentrates on the upper floors, and the application of heavier dosages on the lower floors is recommended. There is little doubt that in most fumigations with hydrocyanic acid the fumigant gradually becomes uniformly distributed throughout the mill. From the three upper curves of fig. 3, which represent the gas concentrations found during the fumigation of mill No. 4 by the liquid method, it will be noted that samples

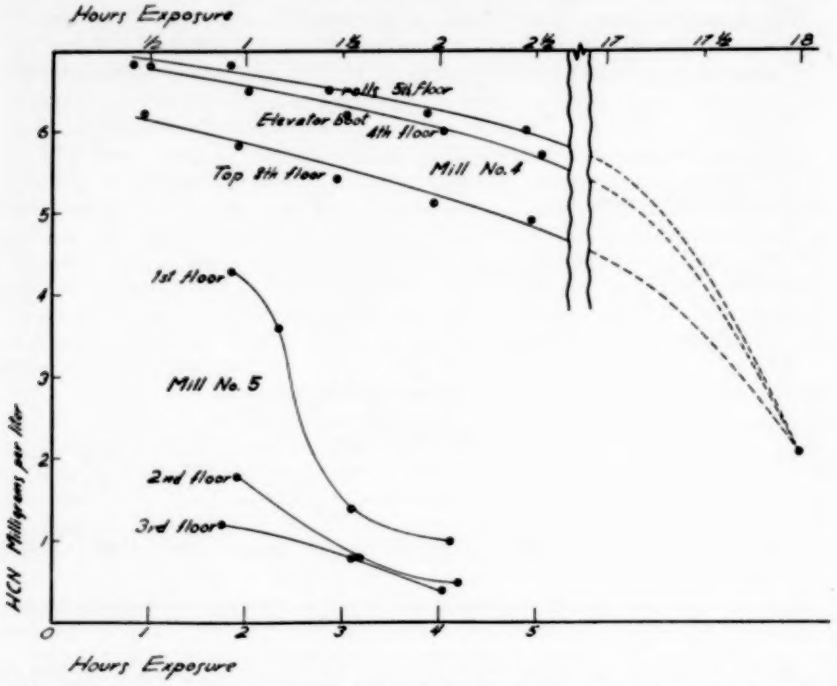

Fig. 3.—Gas concentrations in flour mills Nos. 4 and 5 during fumigation with hydrocyanic acid. Mill No. 4, concrete and steel, fumigated by liquid method, dosage 8.6 ounces HCN per 1000 cubic feet. Mill No. 5, frame and sheet metal, fumigated by liquid method, dosage 9.7 ounces HCN per 1000 cubic feet.

taken 18 hours after the start of a fumigation showed the gas concentrations on the fourth, fifth and top floors of the mill to be exactly the same.

In the fumigation of mill No. 3 by the pot method, with a dosage of 8.2 ounces of hydrocyanic acid per 1000 cubic feet, the maximum concentration obtained appears in fig. 2 as 8.1 milligrams per liter. This figure, however, represents only the initial concentration at the top of the second floor. The figure of 6.3 milligrams per liter more nearly represents the true maximum concentration for the floor as a whole since it is the concentration at both floor and ceiling when the gas reached a state of equilibrium. The maximum concentration obtained in the fumi-

gation of mill No. 4 by the liquid method with a dosage of 8.6 ounces of hydrocyanic acid per 1000 cubic feet was 6.8 milligrams per liter.

The ability of a mill to hold gas is directly dependent on the way it is

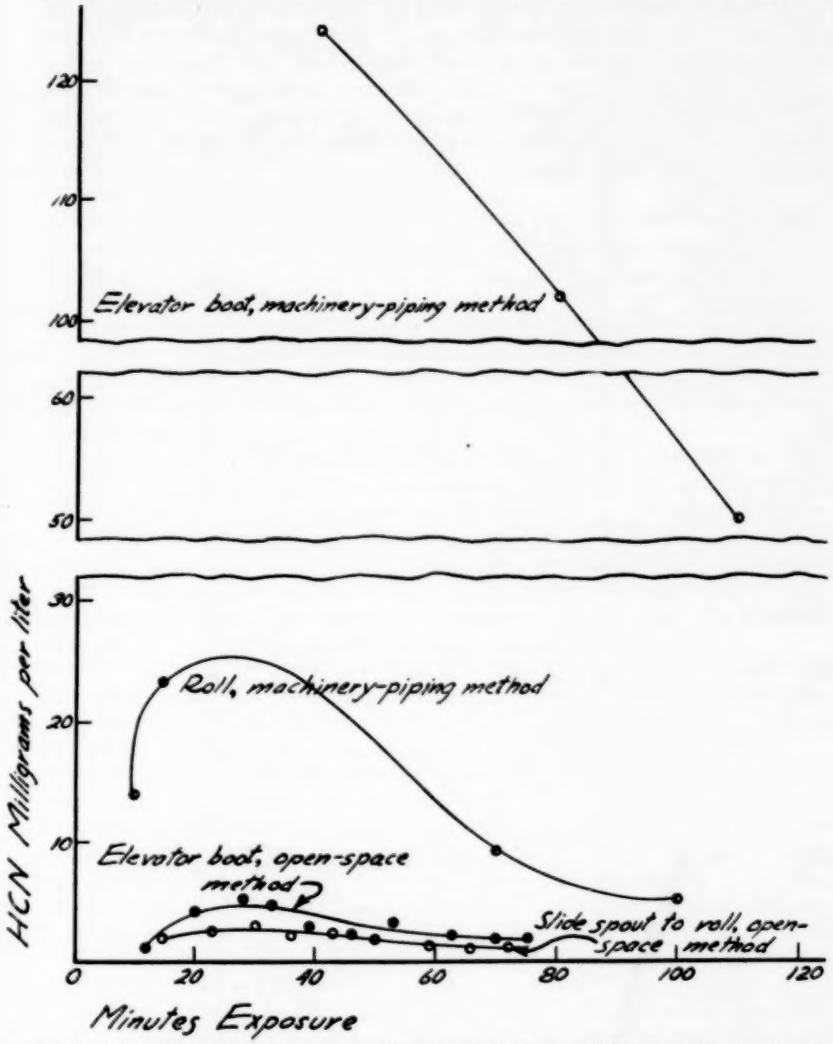

Fig. 4.—Comparison of gas concentrations found in flour mill No. 2 during fumigation by open-space and machinery-piping methods. Dosage of HCN per 1000 cubic feet: Open-space method 11.25 ounces, machinery-piping method 7.8 ounces.

constructed. A modern mill of concrete and steel construction can be made to hold a killing concentration of gas over a long period of time, whereas a frame or frame and sheet metal-covered mill will rarely hold a killing concentration for more than a few hours.

Table 1.—Relative cost and efficiency of different methods of flour-mill fumigation.

Mill No., Construction and Cubic-Foot Content	Method of Fumigation	Dosage HCN Ounces per 1000 Cubic Feet	Cost of Gas per 1000 Cubic Feet	Cost of Labor Before and After Fumigation per 1000 Cubic Feet	Total Cost of Fumigation per 1000 Cubic Feet	No. Test Boxes of Insects Used	No. Samples from Machinery After Fumigation	Total No. Insects in Boxes or Stock Samples	Hours Exposure	Per Cent Kill
1.—Stone and frame, 343,365	P*	7.6	$.31†	$.13	$ .44		41	1661	39	98.5
3.—Frame and sheet metal, 237,905	P	8.2	.26	.22	.48	21		448	17	96
12.—Brick, concrete and steel, 242,228	P	8.12	.32	.28	.60	56	14	3106	20	98.56
13.—Sheet metal, 278,032	P	7.75	.24	.78	1.02	90		1350	39	96.5
13.—Sheet metal, 278,032	P	10.21	.47	.61	1.08	98		2940	24	100
2.—Frame and sheet metal, 149,490	L*	11.25	.70	.53	1.23	70		1220	12.33	99
4.—Concrete, 1,035,705	L	8.6	.54	.59	1.13		25	3028	18	100
5.—Frame and sheet metal, 471,812	L	9.7	.60	.54	1.14	66		1289	24	100
6.—Frame and sheet metal, 149,345	L	9.6	.60	.47	1.07	29		458	10	99.7
10.—Concrete and steel, 658,024	L	8.8	.55	.45	1	74		1037	13	100
11.—Concrete and steel, 1,309,367	L	8	.50	.50	1	80		841	15.75	98
2.—Frame and sheet metal, 149,490	MP*	7.8	.49	.13	.62	37	25	1463	12	99
7.—Frame and sheet metal, 291,500	MP	4.9	.30	.06	.36	174		4339	8	99.8
8.—Frame and sheet metal, 184,758	MP	4.33	.27	.15	.42	46	43	2145	12.5	99
9.—Concrete and steel, 658,024	MP	7.7	.48	.10	.58	19	37	3338	14	98.9

* P, pot method; L, liquid method; MP, machinery-piping method.

† Apparent discrepancies in the cost of the fumigant in fumigations by the pot method are due to variations in transportation costs of materials.

The curves of fig. 3 indicate the gas concentrations found in two mills that were fumigated with liquid hydrocyanic acid in July 1935. Mill No. 4 was built of concrete and steel whereas mill No. 5 was of wooden frame covered with sheet metal. The gas-concentration curves tell the story plainly. The wooden frame mill with the sheet-metal covering could not be made gas tight; and the concentrations, at no time high, dropped rapidly so that within three hours they were reduced to less than 2 milligrams per liter on all floors. The concrete mill was exceptionally tight so that the drop in concentration was very slow and at the end of the fumigation, 18 hours from the start, the concentration on all floors was over 2 milligrams per liter.

The concrete mill contained 1,035,705 cubic feet and received a dosage of 8.6 ounces of hydrocyanic acid per 1000 cubic feet, whereas the wooden frame mill contained 471,812 cubic feet and received a dosage of 9.7 ounces per 1000 cubic feet.

One reason for the remarkable manner in which the gas was held in the concrete mill was the covering with metal caps of all roof vents that were connected with the air-settling chambers. In all fumigations it is advisable to disconnect roof vents from the settling chambers and cover them with tight caps.

During the last few years experimental work has been carried on with a method of applying liquid hydrocyanic acid directly into the milling machinery instead of into the open mill space. A series of pipe lines connects each piece of machinery with a manifold outside the mill. Spray nozzles that open at a set pressure deliver uniform quantities of fumigant to each piece of equipment, and when the pressure is removed they close automatically so that they cannot be clogged with milling stock between fumigations.

With the open-space method of fumigation it is necessary to dismantle the machinery in order to clean out the milling stock, since the low concentrations used will not penetrate very far into flour products. The labor cost of this operation plus the cost of cleaning up the mill and reassembling the machinery after the fumigation usually amounts to as much as, or more than, the cost of the fumigant used.

By applying the fumigant directly into the machinery, concentrations high enough to penetrate the stock left in the milling equipment are obtained with a smaller quantity of gas, hence it is unnecessary to dismantle and clean out the machinery. The saving in time, labor and fumigant makes it possible to fumigate at least twice as often at no greater cost. The cost of installing such a system amounts to about 50 cents per barrel capacity of the mill.

In fig. 4 are shown curves representing the gas concentrations found in the milling machinery of mill No. 2 when fumigated by two different methods. The gas samples were taken from the same locations in the mill during each fumigation. The two upper curves represent the concentrations found during a fumigation when the liquid hydrocyanic acid was applied directly into the machinery, and the two lower curves represent the concentrations found during a fumigation in which the liquid hydrocyanic acid was applied into the mill space.

In the open-space method of fumigation the highest concentration reached at any time in the machinery was 5.5 milligrams per liter, and at the end of one hour the concentration was not over 2.05 milligrams per liter in any part of the mill, whereas in the fumigation in which the fumigant was applied directly into the machinery a concentration of 124 milligrams per liter was found in the elevator boot at the end of 40 minutes and of 50 milligrams per liter at the end of 109 minutes. The concentrations in the rolls did not run so high as in the elevator boots, but at the end of 100 minutes were nearly twice as high as the maximum concentration found in the same locations in the space fumigation at the end of 50 minutes.

There were 105 pounds of liquid hydrocyanic acid used in the space fumigation in contrast to 72 pounds used in the machinery fumigation.

A check on the effectiveness of the fumigations observed was made by sifting insects from samples of milling stock taken from all parts of the

Table 2.—Effect on *Tribolium confusum* of short exposures to hydrocyanic acid gas in mill fumigation.*

Hours of Exposure	No. Test Boxes Used	No. Insects Used	No. Insects Killed	No. Insects Alive	Per Cent Insects Killed
4	18	390	390	0	100
5	30	727	725	2	99.7
5.5	23	618	609	9	98.5
5.75	13	332	326	6	98.2
8	90	1164	1158	6	99.5

* A dosage of 4.9 oz. HCN per 1000 cubic feet was applied directly into the machinery.

milling machinery after the fumigation, or by exposing during fumigation 1-ounce salve tins, screened at top and bottom, containing adults and larvae of the flour beetle *Tribolium confusum*, or by both methods.

Owing to the number of fumigations attended and the large number of insects required for testing purposes it was found impossible to breed in the laboratory a sufficient supply of test insects, hence the insects used in our experiments were often obtained from the mill being fumigated. It was a simple task to sift out the insects from infested stock. Lack of time on these occasions made it impossible to count out exact numbers of insects for each check box.

In table 1 will be found a summary of the observations made on 15 fumigations of flour mills. All three methods of fumigation are included and in one case a comparison is given of the fumigation of the same mill by two different methods.

From a study of the data of table 1 it is evident that remarkably good kills were obtained in all of the mills regardless of the construction of the mill, the variation in dosage, and the method of fumigation used.

Mills fumigated by the pot method showed the poorest kills, probably as a result of too low a dosage and too little care in preparing the mills for fumigation. Large accumulations of milling stock left in the machinery afford protection to insects from the action of the gas. The average cost of fumigation by the pot method per 1000 cubic feet of space in the five fumigations recorded was 72.4 cents.

The best kills were obtained in mills fumigated by the liquid method. In three out of the six fumigations recorded a 100 per cent kill was obtained. These excellent results were due to skillful preparation of the mills and the use of larger dosages of gas. The average cost of $1.09 per 1000 cubic feet of space, however, was considerably higher than that for any other method.

Mills fumigated by the introduction of the fumigant directly into the machinery were treated at a cost lower than those fumigated by the other methods and the kills obtained compared favorably with those obtained in mills fumigated by the liquid method.

The length of exposure necessary in mill fumigation to give satisfactory results has long been a matter for controversy. It has been shown by the various curves presented that gas concentrations fall very rapidly

Table 3.—Effect of a general mill fumigation with hydrocyanic acid gas on eggs of the flour beetle *Tribolium confusum*.*

Fumigation No.	Type of Fumigation	Dosage of HCN, Ounces per 1000 Cu. Ft.	Hours of Exposure	No. Vials of Eggs Used	No. Eggs Fumigated	Per Cent Eggs Killed
1	Machinery piping	5.77	12	19	380	100
2	Liquid	9.6	10	19	380	100
3	Machinery piping	7.6	9	19	380	100
4	Machinery piping	3.8	13	10	200	100
5	Liquid	8.6	18	20	400	100
6	Machinery piping	7.8	12	19	380	100

* Unfumigated eggs held as checks hatched normally.

at the start of a fumigation, few mills retaining killing concentrations of hydrocyanic acid for more than a few hours. To determine the effect on mill insects of shorter exposures than are customarily used, an extra large number of check boxes containing adults and larvae of the flour beetle *Tribolium confusum* were placed throughout the machinery of a mill before it was fumigated and a representative number withdrawn at the end of 4, 5, $5\frac{1}{2}$, $5\frac{3}{4}$, and 8 hour periods after the start of the fumigation. The details of this fumigation are given in table 1 under the designation of mill No. 7.

The effect of these short exposures on the flour beetle is shown in table 2.

Apparently the percentages of insects killed by the short exposures were just as high as for the longer exposures.

To determine the effect of general mill fumigations on eggs of the flour beetle in milling machinery, cotton-stoppered glass vials containing eggs of the flour beetle were buried under accumulations of flour in all parts of the machinery of a number of mills before fumigation. The vials of eggs were recovered after the fumigation and held for observation. As shown in table 3, 100 per cent of the eggs were destroyed in the six fumigations recorded.

PRE-HARVEST SPRAYING OF APPLES FOR REMOVAL OF LEAD RESIDUES[1]

HARLAN N. WORTHLEY and DONALD E. H. FREAR, *The Pennsylvania State College*

The advantages of a wash solution that could be applied to fruit hanging on the trees to reduce the level of spray residues are obvious. Growers already possess the machinery necessary for application. In orchards where residues at harvest customarily exceed the tolerance by a relatively slight margin, such treatment might obviate the necessity for special washing treatment before packing. Where almost continuous spraying produces residues that now require drastic and expensive washing treatment, a successful pre-harvest residue-removing application might permit a milder washing treatment to produce satisfactory results.

During the season of 1935, 18-year old trees of the Stayman Winesap and York Imperial varieties were given cover sprays, as indicated at the top of table 1, on June 18 and 25, July 2 and 16, and August 12. Other Stayman Winesap trees that had received a fourth cover spray early in July were given a final application of oil–lead in mid-August. For a preliminary study of residue-removing sprays, three materials were applied to the trees with a power sprayer on Septerber 15. These materials were hydrated lime 10 pounds per 100 gallons, ammonium nitrate 8 pounds per 100 gallons, and paste *Vatsol* one-half pound per 100 gallons, each at the rate of 10 gallons per tree. A greater concentration of *Vatsol* might have been desirable, but greater amounts produced excessive foaming under agitation in the spray tank.

Duplicate fruit samples for analysis were picked from the lower limbs of the trees, and duplicate determinations for lead were made by the method of Frear & Haley.[2] Samples were taken on September 9, before the sprays were applied, and at harvest on October 15. Further samples taken in an identical manner at harvest were given a one-minute exposure to 1.5 per cent hydrochloric acid in a flotation washer before analyzing for lead.

The complete data for the experiment are presented in table 1. Doubtless because the figure given for each combination involves fruit samples from a single tree only, the data show considerable variation. For this reason no attempt will be made to distinguish between the two control schedules employed on both varieties. However, with one exception (following supplementary treatment with ammonium nitrate) the averages show a residue more difficult to remove from York Imperial than from Stayman Winesap, a result in line with previous apple-washing experience. For this reason, comparisons of the average effectiveness of the three residue-removing sprays tested may be justified.

Two questions present themselves. First, is the natural loss of lead per

[1] Authorized for publication on December 17, 1935, as paper No. 716 in the Journal series of the Pennsylvania Agricultural Experiment Station.

[2] **Frear, D. E. H.** and D. E. Haley. 1934. A simplified method for the rapid determination of lead residues on apples. Pa. Ag. Exp. Sta. Bul. **304**.

Table 1.—Lead residues on apples as affected by supplementary sprays applied on September 15. The amounts are in grains per pound.

Sample Taken	Date	Five Cover Sprays of Lead Arsenate 3:100 plus Lime Sulfur 1:50		Flotation Sulfur 5:100 plus Fish Oil 1:400		Average			*Orthol K* 1:100 in Last Cover Only
		Stayman	*York*	*Stayman*	*York*	*Stayman*	*York*	*Total*	*Stayman*
Before supplementary treatment	Sept. 9	.109	.098	.107	.098	.108	.098	.103	.089
After supplementary spray of hydrated lime 10:100									
At harvest	Oct. 15	.065	.068	.059	.063	.062	.066	.064	
After washing	Oct. 17	.011	.011	.007	.008	.009	.01	.009	
After supplementary spray of ammonium nitrate 8:100									
At harvest	Oct. 15	.047	.071	.079	.039	.063	.055	.059	.068
After washing	Oct. 17	.009	.012	.012	.007	.011	.01	.01	.008
After supplementary spray of paste *Vatsol* .5:100									
At harvest	Oct. 15	.071	.049	.045	.074	.058	.062	.06	.062
After washing	Oct. 17	.009	.015	.009	.009	.009	.012	.011	.008
After no supplementary treatment									
At harvest	Oct. 15	.073	.081	.049	.057	.061	.069	.065	.076
After washing	Oct. 17	.012	.019	.011	.008	.012	.014	.013	.01
Average									
At harvest	Oct. 15	.064	.067	.058	.058	.061	.063	.062	.069
After washing	Oct. 17	.01	.014	.01	.008	.01	.012	.011	.009

Table 2.—Percentage of reduction in lead residues, September 9 to October 15.

	Supplementary Treatment			
	None	Lime	Ammonium Nitrate	*Vatsol*
Average Stayman	43.5	42.6	41.7	46.3
Average York	29.6	32.6	43.9	36.7
Average total	36.9	37.8	42.7	41.7
Increase over check		.9	5.8	4.8
Oil-sprayed Stayman	14.6		23.6	30.3
Increase over check			9	15.7

Table 3.—Percentage of lead residue removed by washing, one-minute exposure to 1.5 per cent HCl.

	Supplementary Treatment			
	None	Lime	Ammonium Nitrate	*Vatsol*
Average Stayman	80.3	85.5	82.5	84.1
Average York	79.7	84.8	81.8	80.7
Average total	80	85.1	82.2	82.5
Increase over check		5.1	2.2	2.5
Oil-sprayed Stayman	86.8		88.2	87.1
Increase over check			1.4	.3

unit of weight while the fruit remains on the trees accelerated by the supplementary treatment? Second, does the use of such a supplementary spray treatment facilitate cleaning after harvest? Table 2, which has been calculated from the figures in table 1, reveals the extent to which the lead residues present on September 9 had disappeared by October 15 due to the growth of the fruit, to weathering and to the supplementary spray treatments of September 15. Because under the conditions of the experiment the first two of these factors exerted a uniform effect, differences may be attributed to the residue-removing sprays.

None of the materials used appeared to increase the loss of lead to any significant extent except from the Stayman Winesap sprayed with lead arsenate plus mineral-oil emulsion. On this fruit *Vatsol* showed considerable benefit in a single test, though under the conditions of the experiment the residues remaining at harvest were far above the legal tolerance. During the period from September 9 to October 15 precipitation totaled 1.66 inches, or about half the normal rainfall for this period. Earlier application of the supplementary sprays, and a subsequent heavy drenching with clear water, particularly if the weather remained dry, might increase the residue-removing effect of these materials.

Table 3 has been calculated in a manner similar to table 2, and shows the extent to which the uniform post-harvest acid wash removed the residues remaining at harvest in the various treatments.

With the possible exception of lime, the figures in table 3 indicate that the supplementary sprays exerted little beneficial effect on the removal of the residue by hydrochloric acid in a flotation washer.

Several generalizations are possible from tables 2 and 3. It was necessary to wash all of the fruit with hydrochloric acid to reduce the residue below the legal tolerance. The effect of this acid wash was to reduce the residues on all treatments to nearly the same level; hence, in the end little practical benefit may be ascribed to any of the supplementary treatments under the conditions of this test. The figures presented in table 2 indicate that under certain conditions some of the supplementary treatments assisted the natural processes of growth and weathering in reducing the residues on the fruit at harvest; with the materials and methods used this benefit was slight. However, since in many Pennsylvania orchards residues at harvest usually exceed the legal tolerance by comparatively slight margins, it is felt that continuation of these studies is justified.

THE ILLINOIS NATURAL HISTORY SURVEY and the Illinois Agricultural Experiment Station, Urbana, have entered into a cooperative agreement with the federal Bureau of Entomology and Plant Quarantine for studies of the corn ear worm. R. A. Blanchard of the Bureau has established headquarters at Urbana and A. F. Satterthwait will join him soon. The objective of the studies is development of better and more practical measures for control of corn ear worm.

E. O. ESSIG, University of California, Berkeley, will be on sabbatical leave from July 1, 1936, to June 30, 1937. From July 1 to September 1, 1936, and from March 1 to June 1, 1937, his address will be Cambridge University, Cambridge, England. During the period from September 1, 1936, to March 1, 1937, his address will be the National Museum du Congo, Tervueren, Belgium.

EASTERN BRANCH

PAPER-READING SESSION, SEVENTH ANNUAL MEETING
Baltimore, Md., November 1935

CODLING MOTH SPRAYING EXPERIMENTS IN PENNSYLVANIA IN 1935[1]

HARLAN N. WORTHLEY, *The Pennsylvania State College*

• Since 1931, studies in the control of the codling moth, *Carpocapsa pomonella* L., have been conducted in one of the most heavily infested orchards in Adams county, Pa., in the center both of the largest commercial fruit-growing region of the state and of the local "codling moth belt." Standard spraying practice here has called for the use of lead arsenate in the petal-fall application and in a varying number of cover sprays. Except in 1933, when growers could not prepare themselves for the removal of lead residues and only three cover sprays were recommended, thorough and timely spraying with lead arsenate in the experimental plots has caused a gratifying reduction in codling moth abundance. As shown

Table 1.—Trend of codling moth population and damage, Heacock orchard, Biglerville, Pa., 1931–35.

Variety	Year	No. Cover Sprays	Lead Arsenate Total *lbs.*	Apples per Tree	Apples Injured *per cent*	Worms per Tree	Residues *Grains per lb.* Lead	Residues *Grains per lb.* Arsenic
Grimes	1931	4	12	719	93.4	751		.017
Grimes	1932	5	14	2359	32.9	243		.025
Grimes	1933	3	6	695	94.3	1092	.005	.002
Grimes	1934	6	18	2510	28	144	.030	.014
Grimes	1935	5	15	106	38.3	14	.051	
Rome	1932	5	15	3101	15.7	132		.006
Rome	1933	3	7	840	80.5	589	.011	.002
Rome	1934	8	24	2380	25.8	39	.096	.036
Rome	1935	5	15	943	14.8	17	.059	

in table 1, the population reached a very low point in 1935, and were it not for the problems of "stinging," spray residues and spray injury, further search for a better codling moth insecticide might be considered unnecesssary.

Materials.—These were the problems in mind when the experiments for 1935 were planned. Fish oil was used with lead arsenate because of its proved benefit in colding moth control and its compatibility with sulfur. Various forms of nicotine[2] were employed, with and without summer oil, because of the promising results of earlier work.[3] Table 2 presents the

[1] Authorized Nov. 9, 1935, for publication as paper 705 in the Journal series, Agricultural Experiment Station.

[2] Field assistance for this project was secured through a grant of funds from the Tobacco By-Products and Chemical Corporation, Louisville, Ky.

[3] Pa. Ag. Exp. Sta. Bul. 285, Mar. 1933. JOUR. ECON. ENT. 27(1):240–4, Feb. 1934. Pa. State Hort. Ass'n News 11(1):34–48, Mar. 1934. Ibid. 12(1):96–107, Mar. 1935.

complete schedule of materials compared in 1935, as used in single-tree plots which were replicated six times in Grimes Golden and five times in Rome Beauty blocks in the Heacock orchard at Biglerville.

Methods.—Spray applications were timed by means of moth catches in bait pails. All spraying was done with a single-nozzle spray gun from the ground alone, at 400 pounds pressure per square inch. Trees were first sprayed from the trunk outward and upward, and then from all

Table 2.—Schedule and materials for codling moth spraying experiments, Heacock orchard, Biglerville, Pa., 1935.

Cover Spray	Treatment Number					
	1	*2*	*3*	*4*	*5*	*6*
First	*May 28* LA 3 lbs.* LS 2 gals.	*May 28* Same as 1	*May 28* Same as 1	*May 28* Same as 1	*May 28* Same as 1	*May 28* Same as 1
Second	*June 7* LA 3 lbs. FS 5 lbs. FO 1 qt. HL 2 lbs.	*June 7* Same as 1	*June 7* Same as 1	*June 7* 155A 6 lbs. Copo 2 lbs.	*June 7* BL40 1 pt. Ben 4.5 lbs. FS 5 lbs.	*June 7* 115B 6 lbs. FS 5 lbs.
Third	*June 18* LA 3 lbs. FO 1 qt. HL 2 lbs.	*June 12* Same as 1	*June 18* Same as 1	*June 17* 155A 6 lbs. OK 3 qts.	*June 17* BL40 1 pt. Ben 4.5 lbs.	*June 17* 155B 6 lbs.
Fourth	*June 27* LA 3 lbs. FS 5 lbs. FO 1 qt. HL 2 lbs.	*June 22* Same as 1	*June 27* 155A 6 lbs. Copo 2 lbs. OK 3 qts. HL .75 oz.	*June 27* 155A 6 lbs. Copo 2 lbs. OK 3 qts.	*June 27* BL40 1 pt. Ben 4.5 lbs. FS 5 lbs.	*June 27* 155B 6 lbs. FS 5 lbs.
Fifth	*July 27* LA 3 lbs. FO 1 pt. HL 2 lbs.	*July 27* Same as 1	*July 9* 155A 6 lbs. OK 3 qts. HL .75 oz.	*July 9* 155A 6 lbs. OK 3 qts.	*July 9* BL40 1 pt. Ben 4.5 lbs.	*July 9* 155B 6 lbs.
Sixth			*July 19* Same as fifth cover	*July 19* Same as fifth cover	*July 19* Same as fifth cover	*July 19* Same as fifth cover
Seventh			*July 30* Same as fifth cover	*July 30* Same as fifth cover	*July 30* BL40 .75 pt. OK 3 qts.	*July 30* Same as fifth cover
Eighth			*Aug. 9* Same as fifth cover	*Aug. 9* Same as fifth cover	*Aug. 9* Same as seventh cover	*Aug. 9* Same as fifth cover

* All amounts are per 100 gallons of water. LA = lead arsenate, LS = lime sulfur, FS = flotation sulfur, FO = fish oil, HL = hydrated lime, 155A and 155B = fixed-nicotine formulas, Copo = *Coposil*, BL40 = nicotine sulfate, OK = *Orthol K Medium*, Ben = wettable bentonite.

angles outside the foliage wall. A definite attempt was made to obtain complete coverage without excessive run-off and with the minimum use of a wide-open gun. All treatments were applied on the same day, with one exception. On June 17 a short shower stopped the work. Trees not dry were resprayed, and the applications were finished on the following day.

The fruit set, particularly of Grimes Golden, was very light and variable, making statistical treatment of the results unsatisfactory. The effectiveness of treatments was determined by counts of the fruit on the trees on July 10–11 (about at the end of first-brood attack), by the scoring of all drop fruit, and by counts at harvest involving all the fruit of

Grimes Golden and a composite two-bushel sample from each tree of Rome Beauty. Spray injury was also noted in these counts, and in addition records were made of injury to the foliage at different times during the season.

Results. *Uninjured Fruit.*—Quite naturally the grower is most interested in the percentage of clean fruit, *i.e.*, that which is neither wormy nor "stung." Table 3 presents these figures for each treatment as the

Table 3.—Percentage of fruit free from codling moth injury, Heacock orchard, Biglerville, Pa., 1935.

Treatment	Grimes Golden				Rome Beauty			
	Apples per Tree	*Per Cent Clean Fruit* July 10	Harvest	Second-brood Injury	Apples per Tree	*Per Cent Clean Fruit* July 11	Harvest	Second-brood Injury
1	106	92.3	61.7	30.6	942	88.6	85.2	3.4
2	116	89	50.7	38.3	715	90	79.2	10.8
3	385	78.5	59.7	18.8	895	85.4	84	1.4
4	91	86.3	70.5	15.8	436	94	94	0
5	229	76.8	43.5	33.3	301	86.2	77.8	8.4
6	238	86.6	67.9	19.7	819	94.8	91.2	3.6

mean of six individual tree percentages for Grimes Golden, and of five for Rome Beauty.

In both varieties the use of *Blackleaf 155A* plus oil (treatment 4) produced the cleanest crop, followed in order by *Blackleaf 155B* (treatment 6), lead arsenate plus fish oil (treatment 1), lead arsenate plus fish oil followed by *Blackleaf 155A* plus oil (treatment 3), lead arsenate plus fish oil in a modified schedule (treatment 2), and tank-mixed nicotine sulfate–bentonite followed by nicotine sulfate–oil (treatment 5).

Table 4.—Development of codling moth larvae in experimental plots, Heacock orchard, Biglerville, Pa., 1935.

Treatment	Grimes Golden			Rome Beauty		
	Worms per Hundred Apples			*Worms per Hundred Apples*		
	July 10	Harvest	Second Brood	July 10	Harvest	Second Brood
1	2.3	13.6	11.3	.7	1.8	1.1
2	2.4	23.6	21.2	.8	2	1.2
3	4.3	17.5	13.2	1.9	2.6	.7
4	5.2	24.6	19.4	1.4	1.8	.4
5	12.9	44.6	31.7	5.9	10	4.1
6	11.7	27	15.3	1.8	3	1.2

The short crop and heavier codling moth infestation in the Grimes Golden block explains the greater damage here. The estimate of damage by the second brood of larvae (the reduction in clean fruit between July 10–11 and harvest) reveals the extent to which sprays containing nicotine continued to protect the fruit. Cessation of the lead arsenate schedules on July 27 allowed considerable increase in damage later, and the wide interval between the fourth and fifth cover sprays in treatment 2 added to its poor showing. The failure of the tank-mixed nicotine–bentonite is shown.

Worminess.—Keen as the interest of the grower may be in a treatment

that will yield the highest percentage of clean fruit in the current season, the eventual solution of his problem rests upon a year-by-year reduction in the codling moth population of his orchard. In table 4 appear the records of worms that escaped the treatments applied. The results are not conclusive, due to the effect of variation in tree yield upon the percentages obtained. It is apparent, however, that the development of larvae of the first brood was kept at a minimum through the use of lead arsenate, and that additional second-brood applications of this material should have been applied to Grimes Golden.

The failure of tank-mixed nicotine–bentonite is shown again in table 4. The relatively slight difference in worminess at harvest between treatment 4 (*Blackleaf 155A* plus oil) and treatment 6 (*Blackleaf 155B* alone) suggests the possibility of adequate late-season control without excessive applications of oil sprays.

Table 5.—Percentage of russeted fruit caused by sprays in codling moth treatments, Heacock orchard, Biglerville, Pa., 1935.

Treatment	Grimes Golden			Rome Beauty		
	July 10	Harvest	After July 10	July 11	Harvest	After July 11
1	20.3	37	16.7	3.1	5.6	2.5
2	10.3	37.5	27.2	4.7	8	3.3
3	15	49.1	34.1	5.8	5.6	0
4	17.3	56.3	39	3.7	3.2	0
5	7.5	22.8	15.3	4.9	5.4	.5
6	13	20.3	7.3	3.	2	0

Spray injury to fruit.—In 1935, spray injury was mostly of the russet type, though in treatments receiving the most lead arsenate a small percentage of the fruit showed the characteristic dark ring of arsenic injury about the calyx. The figures are given in table 5.

Differences in the amount of injury in the various treatments may properly be attributed to the spray combinations employed in this study, but in the absence of unsprayed check trees the contributions of earlier sprays and of frost cannot be separated from the figures reported. The greater damage to Grimes Golden is in part varietal, but may be due also to a general lack of vigor in this block of trees. *Blackleaf 155B* was least harmful to fruit of this variety. The safety of *Blackleaf 155A* could not be determined. The high degree of injury from treatments 3 and 4, although it did not show up immediately, seemed to be the result of applying oil too soon after sulfur. In treatment 3 this interval was from June 7 to June 27, and in treatment 4 from May 28 to June 17. As compared with figures obtained in 1934, the addition of a small amount of hydrated lime to sprays containing lead arsenate and fish oil appeared to reduce the amount of spray injury.

Spray injury to foliage.—Foliage injury by treatments 1 and 2 was characterized by marginal and spot burning, evident June 26, followed by a small amount of yellowing and dropping of leaves that began early in July and continued for the rest of the season. Older leaves were most affected, suggesting cumulative poisoning from arsenic. After every rain storm a few more leaves turned yellow and dropped off.

Marginal and spot burning was common in treatments 3 and 4, and on July 8 leaf-drop was noticeable. Affected leaves showed brown blotches along the midrib and veins, another result of applying oil too soon after sulfur. The injury became more evident during July, and in early August many leaves turned yellow and dropped, and this continued to some extent after showers during the rest of the season.

During the early part of the season the foliage in treatments 5 and 6 remained in good health, but on July 31 a pale cast to the leaves was noticed, with some marginal burning and defoliation, particularly in treatment 6. By August 15 these treatments appeared to be giving the most injury, and during the rest of the season the yellowing and dropping of leaves was more serious in treatment 6 than in any other.

At the end of the season the foliage in treatment 5 looked somewhat better than in the other treatments, where differences were hard to distinguish. In no treatment did it appear that foliage injury was severe enough to affect the vigor of fruit buds. Any effect upon fruit size was obscured by the light and variable crop.

Lead residues at harvest.—Duplicate samples of the fruit in each treatment were picked from the lower limbs at harvest. Duplicate determinations of lead, presented in table 6, were made by D. E. H. Frear of the Department of Agricultural and Biological Chemistry.

Table 6.—Lead residues at harvest, Heacock orchard, Biglerville, Pa., 1935. Amounts are grains per pound.

Treatment	Grimes Golden	Rome Beauty	Average
1	.051	.059	.055
2	.057	.061	.059
3	.030	.027	.029
4	.011	.013	.012
5	.008	.014	.011
6	.012	.008	.010

Five cover sprays of lead arsenate at 3 pounds per 100 gallons, plus fish oil, and ending on July 27, produced the residues shown for treatments 1 and 2, averaging .057 grains of lead per pound of fruit. Three such cover sprays, ending on June 18 and followed by five sprays containing mineral oil (treatment 3), produced lead residues averaging .029 grains per pound. One cover spray of lead arsenate, on May 28, gave a maximum lead load of .014 grains per pound at harvest. This figure approaches the present legal tolerance of .018 grains per pound so closely that a second lead arsenate spray would have placed the fruit above the tolerance, particularly if mineral oil sprays were to be used later in the schedule.

Discussion.—Codling moth populations in Adams county, Pa., have gradually yielded to the continued and careful application of lead arsenate, and this material should still be employed in the first-brood cover sprays. Its high value as a stomach poison is most important at this time, when lack of worm control will allow a build-up in the second brood. The addition of an effective ovicide would prevent a great deal of stinging and thus increase the percentage of clean fruit. *Blackleaf 155A* plus *Orthol K*, and *Blackleaf 155B* alone were so nearly equal in this respect as to suggest the usefulness of the latter when sulfur is present, and

of the former only when sulfur has not been applied during the preceding month at least.

With respect to spray residues it appears that fruit washing cannot be avoided without reducing the use of lead arsenate nearly to the vanishing point. Washing studies in 1935, however, indicate that the residues to be expected from five cover sprays of lead arsenate plus fish oil, or of three cover sprays of lead arsenate followed by mineral oil, can be brought below the present tolerance by a one-minute exposure to cold 1½ per cent hydrochloric acid in a flotation washer.

The nature of the spray injury encountered in 1935 suggests that five cover sprays of lead arsenate may be too many in some orchards or on some varieties of apples. It shows that three weeks is too short a time to allow between applications of sulfur and of mineral oil, and that certain fixed-nicotine compounds are less injurious to the fruit than is lead arsenate, and may be so to the foliage in equal numbers of applications. No perfectly safe and highly effective combination of materials and schedules was discovered. The incompatibility of liquid lime sulfur with fish oil, mineral oil, and fixed-nicotine compounds complicates the problem and places a premium on the early-season control of apple scab with this superior fungicide. Flotation sulfur can be used with fish oil and with the fixed nicotines, and copper fungicides with mineral oil.

To sum up the experimental evidence to date, the safest and most effective treatment for codling moth control in south-central Pennsylvania for 1936 appears to consist of four first-brood cover sprays of lead arsenate at approximately 10-day intervals from early June to early July, the first two sprays to contain fish oil and the last two *Blackleaf 155B* of a similar but less injurious formula if one can be developed. For the few orchards where second-brood sprays may be necessary the omission of sulfur after the third week in June is indicated, for summer oil with nicotine sulfate or with *Blackleaf 155A* appears to be the only safe and effective substitute for lead arsenate for second-brood codling moth control. Because of the expense of such a schedule, the importance of attempting to secure a high degree of control of the first brood during June is stressed.

LABORATORY TESTS OF PHENOTHIAZINE AGAINST CODLING MOTH LARVAE

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For several years the authors have been experimenting with various synthetic organic compounds to test their effectiveness as insecticides against the codling moth, *Carpocapsa pomonella* L. The most promising of these materials was found to be phenothiazine. A preliminary note on the use of this material appeared recently in the Journal.[1]

[1] Smith, L. E., F. Munger, and E. H. Siegler. 1935. Phenothiazine, a promising new insecticide. Jour. Econ. Ent. 28(4):727–8. Aug.

The development of phenothiazine as an insecticide, some methods of preparing it, and experiments with respect to its toxicity to newly hatched larvae of the codling moth, conducted for the most part under laboratory conditions, will be described in this paper.

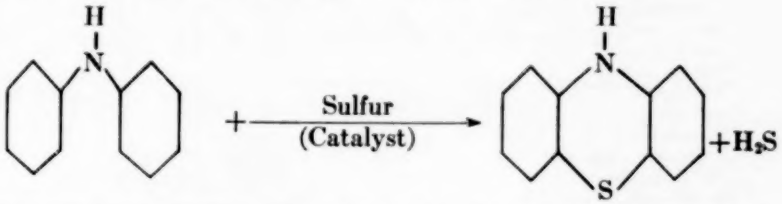
Phenothiazine is a light yellow crystalline material melting at 180° C (356° F). Its final purification is best effected by recrystallization from benzene or toluene. It is only sparingly soluble in the cold in the usual organic solvents, mineral and vegetable oils, and is insoluble in water.

Preparation.—The method first used in the Division of Insecticide Investigations for preparing this compound consisted in heating 1 mole of diphenylamine with 2 moles of sulfur at a temperature of 140–160° C (284–320° F), with aluminum chloride as the catalyst, until the evolution of hydrogen sulfide ceased. The material produced in this way will be referred to as phenothiazine I. This method was also used on a semi-commercial scale, and the resulting material will be referred to as phenothiazine II.

It was later found that when this commercial material was extracted with ether in a Soxhlet apparatus only about 55 per cent was removed. This soluble material proved to be practically pure phenothiazine, as determined, after recrystallization from benzine, by a mixed melting point with an authentic sample. The 45 per cent insoluble in ether was found to be comparatively nontoxic to codling moth larvae.

The method of preparation was then modified by substituting iodine for aluminum chloride as the catalyst, and the resulting material was found to be nearly pure before recrystallization. This reaction can also be carried out in a solvent medium, for example, ortho dichlorobenzene. This modification has been found applicable for use on a semi-commercial scale, and the material so prepared will be referred to as phenothiazine III.

The reaction involved is expressed by the following equation:



Preliminary toxicity tests.—The first test of phenothiazine I against insects was conducted against larvae of the mosquito *Culex quinquefasciatus* Say under laboratory conditions, by J. W. Bulger of the Division of Control Investigations.[2] In view of the favorable results it was suggested that phenothiazine might give promise as an insecticide in the control of the codling moth.

Accordingly a spray test was made on April 17, 1934. In preparing phenothiazine I for spray purposes, the first obstacle encountered was

[2] **Campbell, F. L.,** W. N. Sullivan, L. E. Smith and H. L. Haller. 1934. Insecticidal tests of synthetic organic compounds—chiefly tests of sulfur compounds against culicine mosquito larvae. Jour. Econ. Ent. 27(6):1176–85. Dec.

the difficulty of wetting it. As a means of getting it into a water suspension, fuller's earth was at first employed. Phenothiazine was used at the rate of 2 pounds per 50 gallons of water and fuller's earth at 6 pounds per 50 gallons of water. This preliminary experiment (test 1), the results of which are included in table 1, indicated that phenothiazine I was worthy of further investigation. Other tests (tests 2 and 3) were made in comparison with lead arsenate applied at the same dosage. These results were also favorable for phenothiazine I.

Table 1.—Laboratory tests of phenothiazine as compared with lead arsenate against codling moth larvae (local stock), Takoma Park, Md., April-May 1934.

Test	Spray Material	Apple Plugs		
		Number	Per cent Wormy	Per cent Stung
1	Phenothiazine I, fuller's earth	25	4	0
2	Phenothiazine I, fuller's earth	27	18	0
	Lead arsenate	27	29.6	0
3	Phenothiazine I, fuller's earth	23	30.4	0
	Lead arsenate	23	26.1	0

Laboratory tests of field-sprayed fruit.—Samples of fruit were obtained from field plats in experiments conducted in 1934 by the Bureau of Entomology and Plant Quarantine and the West Virginia Agricultural

Table 2.—Comparison of phenothiazine II and lead arsenate as insecticides against codling moth larvae (local stock). Laboratory tests with field-sprayed fruit, Takoma Park, Md., 1934.

Test	Spray Material	Fruit Sprayed in Field 1934	Larvae Hatched	Days From Time of Spraying to Hatching of Larvae	Number	Per Cent Wormy	Per Cent Stung
1	Phenothiazine II, bentonite, fish oil	June 27	July 20	23	51	96.1	0
	Lead arsenate	26	20	24	52	63.5	25
2	Phenothiazine II, bentonite, fish oil	July 18	23	5	73	41.1	30.1
	Lead arsenate	19	23	4	69	39.1	33
3	Phenothiazine II, bentonite, fish oil	18	Aug. 8	21	66	62.1	9.1
	Lead arsenate	19	8	20	68	45.6	20.6
4	Phenothiazine II, bentonite, fish oil	Aug. 6	11	5	63	50.8	7.9
	Lead arsenate	6	11	5	60	36.7	23.3

Experiment Station at Kearneysville, in charge of Edwin Gould. In these experiments the commercial phenothiazine II was used with bentonite, home mixed in the first test but later mixed in a paint mill before being diluted for spraying purposes. Since nothing was known at the time with respect to the adhesiveness of phenothiazine, fish oil was added in all sprays. The materials were used in the following dosages: Phenothiazine 2 pounds, plus bentonite 2 pounds, plus fish oil 1 quart, per 50 gallons of water; lead arsenate 1½ pounds per 50 gallons of water.

Sample apples, picked at random from four quarters of trees sprayed with phenothiazine II and from trees sprayed with lead arsenate at approximately the same time, were carefully handled and brought to the laboratory, where plugs were cut from the fruit and exposed to newly hatched codling moth larvae.

The results of these experiments are given in table 2. It will be noted that, following the June applications (test 1), there were intervals of 23 and 24 days before infestation. The percentages of wormy fruit indicate

Table 3.—Comparison of the toxicity of phenothiazine II and phenothiazine III, and of phenothiazine II with different wetting agents, to codling moth larvae, laboratory tests, Takoma Park, Md., 1934.

Test	Spray Material	Apple Plugs		
		Number	Per Cent Wormy	Per Cent Stung
	Local Stock, October 1934			
1	Phenothiazine II, bentonite	85	52.9	2.3
	Phenothiazine III, bentonite	97	20.6	1
	Arkansas Stock, December 1934			
2	Phenothiazine II, bentonite	234	68.8	3.4
	Phenothiazine III, bentonite	102	45.1	0
3	Phenothiazine II, fuller's earth	102	72.5	3.9
	Phenothiazine II, potassium fish-oil soap	97	69.1	4.1

that lead arsenate retained its effectiveness much better than phenothiazine. The apples sprayed with lead arsenate had 25 per cent of stung fruit, whereas those sprayed with phenothiazine had none.

In another lot of fruit (test 2) infested four and five days after being sprayed with lead arsenate and phenothiazine, respectively, the effectiveness of these compounds was about equal, as shown by the percentages of wormy and stung fruit.

In test 3, with 21 and 20 days between spraying and infestation, lead arsenate resulted in a smaller percentage of wormy plugs than pheno-

Table 4.—Relative toxicity of phenothiazine II and its ether-soluble and ether-insoluble fractions, Takoma Park, Md., January 1935.

Spray Material *Arkansas Stock*	Apple Plugs		
	Number	Per Cent Wormy	Per Cent Stung
Phenothiazine II, bentonite	99	46.5	1
Ether-soluble fraction of phenothiazine II, bentonite	103	23.3	0
Ether-insoluble fraction of phenothiazine II, bentonite	97	63.9	0

thiazine. Again the percentage of stings was greater for lead arsenate.

On fruit sprayed August 6 and infested five days later (test 4), phenothiazine gave the higher percentage of wormy fruit, but the percentage of stung fruit was much higher where sprayed with lead arsenate.

Laboratory-sprayed apple plugs.—The results in the field with phenothiazine II were not so favorable as had been expected. Accordingly, it was deemed advisable to check its toxicity with laboratory tests. In two tests, one conducted in October and the other in December 1935, pheno-

thiazine II was compared with phenothizaine III. The same dosage was used as in the field tests, and bentonite was used as the wetting agent in both cases. The data in table 3 clearly indicate that the impure phenothiazine II was not so toxic as the pure phenothiazine III. In December further tests were made with other wetting agents, fuller's earth (2 pounds per 50 gallons) and potassium fish-oil soap (one-quarter pound per 50 gallons), and these materials did not increase the toxicity of phenothiazine II.

Table 5.—Miscellaneous laboratory tests on the toxicity of phenothiazine against codling moth larvae, Takoma Park, Md., January-March, 1935.

Spray Materials and Amounts per 50 Gallons	Apple Plugs		
	Number	Per Cent Wormy	Per Cent Stung
Arkansas Stock			
Check (unsprayed)	113	94.6	0
Lead arsenate 2 lbs.	103	41.7	0
Lead arsenate 2 lbs., bentonite 2 lbs.	99	52.5	11.1
Phenothiazine III 2 lbs., bentonite ½ lb.	96	9.4	1
Phenothiazine III 2 lbs., tar soap ¼ oz.	102	16.7	1
Phenothiazine III 2 lbs., bentonite ½ lb., lime sulfur 1½ gals.	91	4.5	1.1
Phenothiazine III 2 lbs., tar soap ¼ oz., lime sulfur 1½ gals.	97	3.1	0
Local Stock			
Phenothiazine III 2 lbs., bentonite 1 lb. (plugs infested immediately)	100	2	0
Phenothiazine III 2 lbs., bentonite 1 lb. (plugs infested five days after spraying)	100	6	0
Phenothiazine III 2 lbs., bentonite 1 lb.	96	8.3	0
Phenothiazine III 2 lbs., tar soap ¼ oz.	108	3.7	0
Lead arsenate 2 lbs.	187	26.2	8
Lead arsenate 2 lbs., bentonite 1 lb.	105	18.1	2.9
Phenothiazine III 2 lbs., bentonite ½ lb.	94	20.2	1.1
Phenothiazine III 2 lbs., bentonite 2 lbs.	100	18	1
Phenothiazine III 5 lbs., bentonite 5 lbs.	100	23	0
Phenothiazine III 2 lbs., bentonite 5 lbs., lime sulfur 1½ gals.	104	9.6	1

Since there appeared to be a considerable difference in toxicity between phenothiazine II and phenothiazine III, the ether-soluble and ether-insoluble portions of II were tested against codling moth larvae. As shown in table 4, the ether-soluble fraction, which was practically pure phenothiazine, was much more toxic than the ether-insoluble fraction. The commercial phenothiazine II, from which the fractions were made, was intermediate in toxicity between the two fractions.

In table 5 the results of miscellaneous experiments are given. As usual, when the fruit was in good physical condition a high percentage of wormy plugs was obtained when they were not sprayed. Phenothiazine II was very toxic to the larvae, comparing favorably with lead arsenate in all the tests. Its effectiveness was not reduced when it was combined with lime sulfur solution.

Phenothiazine III was used with bentonite 1:50 in two tests. In one of these tests apple plugs were exposed to larval attack as soon as the spray had dried, while in the other the sprayed plugs were held five days before being subjected to the larvae, to ascertain what loss in toxicity

might occur. In the latter case the sprayed fruit was held in a dark constant-temperature chamber at 80° F (26.7° C). The entrance into the fruit exposed five days was 4 per cent less than into the freshly infested fruit. In general the initial effectiveness of phenothiazine III was approximately the same whether combined with tar soap or with bentonite.

Summary and conclusions.—The toxicity of phenothiazine to larvae of the codling moth, *Carpocapsa pomonella* L., has been studied in the laboratory. Most of the tests were on fruit sprayed and infested in the laboratory by the apple-plug method, and the toxicity was compared with that of lead arsenate. Other tests included infestation of field-sprayed fruit in the laboratory, a comparison of the effectiveness of pure and commercial phenothiazine, and a study of the effect of a few wetting agents on the toxicity of phenothiazine.

In general these tests have shown that the initial toxicity of pure phenothiazine is superior to that of lead arsenate. The reduction in the percentage of stings on fruit sprayed with this material is frequently striking. Commercial phenothiazine (55 per cent phenothiazine), however, was less effective than lead arsenate, especially when the sprays had been subjected to normal weathering. The physical properties of phenothiazine are in general fairly satisfactory for insecticidal purposes and for an organic compound its cost is relatively low. However, the practicability of using this material as an insecticide for the codling moth can be determined only by adequate experiments under orchard conditions.

TESTS OF INSECTICIDAL EFFICIENCY OF SOME CONTACT SPRAYS AGAINST CODLING MOTH EGGS

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During the past eight years the use of refined petroleum oil has become more or less general in regions where codling moth has been difficult to control. The oil is employed as a spreader and sticker for lead arsenate and also as an ovicide. Under conditions obtaining in the Appalachian fruit region it is frequently desirable to use a fungicide in combination with the insecticide in important cover sprays for codling moth control. De Ong, Knight & Chamberlin[1] have pointed out, however, that certain materials, including lime, absorb oil and by their absorptive capacity may prevent the oil from coming in contact with the object sprayed and thus reduce insecticidal efficiency. Porter & Sazama[2] found that Bordeaux mixture at a strength generally used as a fungicide reduced the efficiency of dormant oils against San Jose scale when the concentration of oil was less than 1.5 per cent in dormant sprays or up to 2 per cent in summer spraying. The purpose of this paper is to present the results

[1] 1927. Hilg. 2:351–84.
[2] 1930. Jour. Ag. Res. 40:755–66.

of tests made against codling moth eggs with summer oil alone and in combination with Bordeaux mixture, and also to compare the ovicidal efficiency of certain vegetable oils and other well-known contact insecticides.

The senior author, assisted by Earnest A. Walker, is responsible for the work done at Winchester (tables 1 and 2), while the junior author

Table 1.—Experiments with ovicides against eggs of the codling moth, Winchester Va., 1934.

Materials and Amounts per 100 Gallons	No. of Eggs Sprayed	No. of Eggs Hatched	Per Cent Hatched	Per Cent Control
Orthol K 2 qts.	1353	102	7.5	91.4
Orthol K 2 qts., copper sulfate 2 lbs., hydrated lime 6 lbs., lead arsenate 3 lbs.,	1342	792	59	32.4
Summer scalecide 1 gal.	1632	539	33	62.2
Summer scalecide 1 gal., nicotine sulfate 1 pt.	2157	488	22.6	74.1
Summer scalecide 1 gal., nicotine sulfate 1 pt., *Areskap* .1%	3124	419	13.4	84.6
Summer scalecide 3 qts.	1785	771	43.1	50.6
Summer scalecide 3 qts., *Areskap* .1%	1333	993	74.4	14.8
Summer scalecide 2 qts.	1592	817	51.3	41.3
Orthol K 1 gal.	2858	114	3.9	95.5
Orthol K 1 gal., copper sulfate 2 lbs., hydrated lime 6 lbs., lead arsenate 3 lbs.	4815	456	9.4	86.9
Orthol K 1 gal., nicotine sulfate 1 pt.	1553	15	.9	98.9
Orthol K 1 gal., nicotine sulfate 1 pt., *Areskap* .1%	2860	247	8.6	90.1
Orthol K 3 qts.	2075	73	3.5	95.9
Orthol K 3 qts., copper sulfate 2 lbs., hydrated lime 6 lbs., lead arsenate 3 lbs.	1900	632	33.2	62
Orthol K 3 qts., *Areskap* .1%	883	217	24.5	71.9
Nicotine sulfate 1 pt.	4642	783	16.8	80.7
Nicotine sulfate 1 pt., *Areskap* .1%	4390	2876	65.5	25
Black Leaf 155 5 lbs.	2895	1510	52.1	40.3
Loro 1 qt.	1695	1330	78.4	10.2
Loro 1 qt., *Areskap* .1	1740	1408	80.9	7.4
Loro 1 pt.	1472	1303	88.5	0
Checks (not sprayed)	9907	8668	87.4	

did the work at Blacksburg (table 3). At Winchester the eggs were deposited on Kieffer pear leaves and the leaves were suspended from limbs of apple trees by means of paper clips and string for the purpose of spraying. In each test we used eggs of different but known ages, the ages usually ranging from less than one day to eggs due to hatch within a short time. Except in the case of nicotine, there was no consistent relation between age of the eggs and effectiveness of the ovicide. For

this reason the results obtained with each insecticide or combination show the totals for all tests made each season. A power sprayer and a hand sprayer were employed in making the applications. After the spray had dried, the leaves were removed from the trees and kept in the laboratory until examined. Unsprayed checks accompanied each test but in tables 1 and 2 the checks are grouped for the season because there was but slight variation in the hatch. At Blacksburg (table 3) the eggs were deposited on pieces of window glass. Prior to each test the infertile eggs were removed from glasses to be sprayed as well as from the checks. Where the same check was used for more than one test, the tests are grouped together with the check immediately below. Eggs of different ages were used in each test and the procedure followed was similar to that reported by Schoene & Jefferson.[3]

Table 2.—Experiments with ovicides against eggs of the codling moth, Winchester, Va., 1935.

Materials and Amount per 100 Gallons	No. of Eggs Sprayed	No. of Eggs Hatched	Per Cent Hatched	Per Cent Control
Summer scalecide 1 gal.	3320	2176	65.5	28.8
Gulf oil 7 pts., pine-tar soap 1 lb., copper sulfate 2 lbs., hydrated lime 6 lbs.	2120	713	33.6	63.5
Gulf oil 5½ pts., copper sulfate 2 lbs., hydrated lime 6 lbs., lead arsenate 3 lbs.	1866	297	15.9	82.7
Orthol K 1 gal., copper sulfate 2 lbs., hydrated lime 6 lbs., lead arsenate 3 lbs.	1745	100	5.7	93.8
Orthol K 3 qts., copper sulfate 2 lbs., hydrated lime 6 lbs., lead arsenate 3 lbs.	1495	129	8.6	90.6
Paraffin-wax emulsion (20% wax)	440	0	0	100
Paraffin-wax emulsion (2% wax)	3284	2608	79.4	13.7
Checks (not sprayed)	5591	5150	92.1	

All of the ovicides used at Winchester were already emulsified or miscible with water when obtained, except the white oil obtained from the Gulf Refining Company. This oil was dispersed in the spray tank by agitation and pumping in the presence of either pine-tar soap or Bordeaux mixture according to the formulae given in table 2. A bentonite mixture (prepared by soaking 60 grams of bentonite in 980 cc. of hot water and agitating the mixture after the bentonite had settled to the bottom of the container) was used to emulsify the vegetable oils, but in the cases of rosin oil and linseed oil powdered acacia was used in addition to the bentonite. Stock emulsions were prepared by agitation with an electric mixer which was made by R. G. Henderson. The stocks were: Cottonseed oil 2 parts and bentonite mixture 1 part, corn oil or soybean oil 1 part and bentonite mixture 2 parts, linseed oil and bentonite mixture 100 cc. each and then 20 grams of acacia added. The rosin-oil stock emulsion was prepared by mixing 10 grams of acacia

[3] 1935. Jour. Econ. Ent. **28**(1):182–4. Feb.

with 100 cc. of bentonite mixture, to which was then added 150 cc. of rosin oil. All the stocks were diluted with water to give the proportion of oil shown in table 3, except the cottonseed-oil stock, which was diluted

Table 3.—Experiments with ovicides against eggs of the codling moth, Blacksburg, Va., 1935.

Materials and Amount per 100 Gallons	No. of Eggs Sprayed	No. of Eggs Hatched	Per Cent Hatched	Per Cent Control
Orthol K 2 qts.	242	63	26	72.9
Check	102	98	96.1	
Orthol K 3 qts.	124	41	33.1	65.5
Orthol K 4 qts.	324	27	8.3	91.4
Check	176	169	96	
Orthol K 5 qts.	368	17	4.6	95.2
Orthol K 6 qts.	332	33	9.9	89.7
Check	238	229	96.2	
Cottonseed oil 2 qts.	289	14	4.8	94.2
Check	122	101	82.8	
Cottonseed oil 3 qts.	246	7	2.8	97
Check	60	56	93.3	
Cottonseed oil 4 qts.	306	5	1.6	98.4
Check	68	68	100	
Cottonseed oil 5 qts.	398	5	1.3	98.7
Check	139	138	99.3	
Cottonseed oil 6 qts.	274	1	.4	99.6
Corn oil 2 qts.	257	2	.8	99.2
Check	108	106	98.1	
Corn oil 3 qts.	267	0	0	100
Corn oil 4 qts.	320	1	.3	99.7
Corn oil 5 qts.	387	0	0	100
Corn oil 6 qts.	208	0	0	100
Soybean oil 2 qts.	161	0	0	100
Check	224	204	91.1	
Soybean oil 3 qts.	297	1	.3	99.7
Soybean oil 4 qts.	317	0	0	100
Check	176	165	93.8	
Soybean oil 5 qts.	207	0	0	100
Soybean oil 6 qts.	191	0	0	100
Check	131	127	96.9	
Linseed oil 2 qts.	229	97	42.4	55.8
Linseed oil 3 qts.	222	25	11.3	88.2
Linseed oil 4 qts.	355	24	6.8	92.9
Check	149	143	96	
Linseed oil 5 qts.	227	0	0	100
Check	71	68	95.8	
Linseed oil 6 qts.	147	0	0	100
Rosin oil 2 qts.	148	49	33.1	65.8
Check	32	31	96.9	
Rosin oil 3 qts.	164	25	15.2	84.2
Check	50	48	96	
3% Bentonite water	270	237	87.8	11.6
Check	141	140	99.3	

in a 2 per cent bentonite–water mixture. Wherever proprietary insecticides were used the dilution refers to the amount of the stock material used rather than to the proportion of active ingredient.

A summary of the number of eggs (all ages included) sprayed, hatched, and control obtained with each ovicide alone or in combination for each season used, may be found in tables 1, 2 and 3. The control was calculated according to Abbott's formula.[4]

Except for nicotine there was no consistent relation between kill obtained by the various insecticides and age of the eggs. With nicotine, however, the ovicidal efficiency increased as the age of the eggs increased. For example, when nicotine sulfate (1 pint in 100 gallons) was used against eggs less than 48 hours old, and which did not normally hatch until five and three-fourths days after the time of spraying, the kill was relatively low (67.1 per cent hatched), but in the same test against eggs two and three days older, the kill was materially increased (only .2 to .6 per cent hatched). A similar relation was found in the case of nicotine bentonite (*Black Leaf 155*), except that in no instance was the material as effective in killing eggs as nicotine sulfate.

The use of one of the recently developed wetting agents (*Areskap*) as a spreader for oil, nicotine and other sprays was attempted at the rate of .1 per cent by volume. The wetting agent caused excessive run-off and thus materially reduced insecticidal efficiency. The advisability of employing such efficient wetting agents will depend on careful determination of the dilution that can be used to give spreading without influencing the normal run-off. This may vary with different waters and also with different spray materials.

Some of the vegetable oils gave a slightly higher percentage of control than mineral oil emulsion when used at comparable oil dilutions. For example, cottonseed oil, corn oil and soybean oil at the rate of 4 quarts per 100 gallons gave slightly better control than *Orthol K* emulsion (80 to 83 per cent oil) at the rate of 5 quarts per 100 gallons. As far as the writers know, the vegetable oils mentioned in this paper have not been tested extensively on apple foliage and therefore little is known concerning their effect on the trees.

Summary.—*Orthol K* emulsion at the rate of 2, 3 and 4 quarts per 100 gallons were used alone and in combination with Bordeaux mixture, and in each instance ovicidal efficiency was reduced by the Bordeaux mixture, but when used at the rate of 4 quarts per 100 gallons the ovicidal efficiency was not reduced to a considerable degree.

Oil in combination with Bordeaux mixture in the tests of 1935 resulted in a relatively high percentage of control, except in the case of white oil dispersed with pine-tar soap to which Bordeaux mixture was then added. In this formula the run-off appeared to be excessive.

Summer scalecide (a new preparation was used in 1935) failed to give satisfactory control, likewise paraffin-wax emulsion, except when the undiluted stock emulsion, containing 20 per cent wax, was used.

A wetting agent (*Areskap*) at the rate of .1 per cent by volume caused excessive run-off of all sprays in which it was used.

At comparable oil dilutions certain vegetable oils were equal to or slightly more effective than refined petroleum oil as an ovicide in tests on codling moth eggs.

[4] 1925, Jour. Econ. Ent. 18:265–7.

NOTES ON THE APPLE MAGGOT

PHILIP GARMAN, *Connecticut Experiment Station, New Haven*

It is possible to breed the apple maggot, *Rhagoletis pomonella* W., throughout the winter, and the flies may be utilized for control experiments. Prior to the work of Fluke[1] this was considered impossible.

Our method consists of bringing field-collected flies to the laboratory where they are kept in small cages with food and water. The air within the room is conditioned to 76° F and 60 per cent relative humidity. The flies are brought to the laboratory direct from the field cages. Green apples are placed within the cages after mating occurs and oviposition takes place regularly after it begins. The food supplied is honey or honey and yeast and water is kept constantly before the flies.

Having determined the length of life and period of oviposition, a number of control measures were tested in the laboratory in order to learn, if possible, how they worked. It was noted among other things that flies lived for a considerable length of time even when provided with arsenate of lead-coated fruit. A series was then begun in which various substances were used to coat the fruit, the regular water supply having first been removed and water sprinkled daily on the fruit instead. At the end of 20 days the apples were removed, dead flies noted and egg punctures counted. Although flies lived for a considerable length of time in cases with arsenate of lead coated-fruit, few or no eggs were laid. This same condition is true for cryolite and to a lesser extent for derris.

Field experiments for the last two years bear out this conclusion for cryolite, which appears to be only slightly less effective than arsenate of lead for apple maggot control. Our first field experiment with derris was conducted this year and produced unfavorable results for the material. More work, however, is needed to establish whether it has enough action in the field to be considered.

In addition to the above tests, 24 to 48-hour tests were run with various materials to determine whether any of them have properties which would prevent oviposition on the part of the fly. In these tests a sprayed and unsprayed apple were hung in the same cage, care being taken to select apples of the same size and condition. Egg punctures were counted in both apples at the end of the period. It was soon observed that certain materials, notably talc, sulfur and lime, have a tendency to prevent oviposition.

Table 1.—Talc, lime and sulfur dusts as repellents for the apple maggot, laboratory experiment.

	TREATED	CHECK
Talc	3	94
Lime	5	93
Sulfur	60	218
Control	99	113

Figures are number of egg punctures per apple. In the controls the number of punctures are graded into smaller and larger numbers, the larger number being comparable to the check apple of the treated cages.

Sprays of lime and glue proved as effective as any in these experiments, and field tests were conducted in three different orchards, using the combination. There was a considerable reduction in the number of

[1] 1933. JOUR. ECON. ENT 26(6):1111–12. Dec.

maggoty apples over check trees in two orchards. Although the comparison of glue–lime and lead arsenate–lime in the third gave results in favor of lead arsenate, it is worth while to remark that the lead arsenate-sprayed plot was above tolerance for lead at harvest.

Table 2.—Laboratory control of apple maggot. Same cages with the same flies used throughout the experiment.

	Cage Number	Egg Punctures Sprayed	Egg Punctures Check	Per Cent Reduction
		August 13–15		
Lime 2 lbs., glue ¼ gm., water 100 cc.	1	60	111	
	2	3	43	
	3	0	33	
	4	6	47	
		69	234	71
		August 15–17		
Lead arsenate ¼ gm., water 100 cc.	1	50	44	
	2	9	6	
	3	16	6	
	4	16	20	
		91	76	0
		August 17–19		
Check	1	33	49	
	2	8	11	
	3	11	28	
	4	23	24	
		75	112	32.2
		August 19–21		
Check	1	29	43	
	2	14	20	
	3	4	5	
	4	11	16	
		58	84	31
		August 21–23		
Lime 2 lbs., glue ¼ gm., water 100 cc.	1	14	88	
	2	3	58	
	3	2	10	
	4	0	38	
		19	194	91.5

An interesting experiment with field-collected flies was conducted during the summer, table 2. Here the lead arsenate in itself had no repellent action when suddenly presented to ovipositing flies, whereas lime had considerable action (but not so much as during the winter). It is apparent, therefore, that under some conditions apple maggot flies will oviposit in arsenate of lead or lime-coated fruit, notably when, as in this experiment, they suddenly encounter sprayed fruit at the height of oviposition. Under these conditions lime may be of more value than lead arsenate.

Summary.—Apple maggot flies may be successfully bred under laboratory conditions during the winter. Lime, talc and sulfur have considerable repellent action toward oviposition. The adult fly is affected by cryolite almost if not quite the same as lead arsenate.

COMSTOCK'S MEALYBUG AS AN APPLE PEST

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An outbreak of Comstock's mealybug in Virginia apple orchards in 1934 caused heavy losses. Fifty per cent of the fruit was heavily coated with a sooty fungus which grew in the honeydew. The insect was controlled by tar and petroleum oil applied as a dormant spray after the trees had been scraped. Nicotine sprays against the first brood showed some promise.

In the central Atlantic states and northward mealybugs are generally not pests of plants grown outdoors. Comstock's mealybug, *Pseudococcus comstocki* Kuwana, is an exception, for it is an important pest of umbrella catalpa, and attacks many other plants. It is often found on apple, but heretofore has not been reported in sufficient numbers to be regarded as a pest. During 1934 a very severe outbreak of this mealybug occurred on apple in a restricted area of Albemarle county, Va.

In July 1934, when this outbreak was first reported, parts of three commercial orchards were heavily infested. The insects were present in large numbers on the trunks, branches and fruits; but only scattered individuals were on the foliage. On the trunks and branches the colonies were commonly found on pruning scars and other wounds where there was a growth of new bark; and many insects were on the water sprouts. The infestation on the fruit was heaviest in the calyx and stem basins. On Albemarle Pippin, which has an open calyx, many of the bugs were within the calyx cavities.

The owners of the affected orchards reported that there had been a light infestation in 1933, and that some fruit had shown the characteristic sooty deposits, but that the loss had been unimportant.

The feeding of the insects evidently caused very little direct damage to trees or fruit. There was no formation of galls on the trunks or branches. Heavily infested trees appeared as thrifty as those nearby which were uninfested. Some heavily infested branches lost their foliage earlier than other parts of the same tree, but the same differences could be observed on trees which were not infested.

The loss from mealybug infestation was the result of the deposits of honeydew which supported the growth of a sooty fungus. When these deposits occurred on the fruits, as was the case with most of those which were infested, there was formed a very tenacious sooty coating which was not removed by the washing methods employed. In 1934, 50 per cent of the fruit from the infested area was so heavily coated that its value was diminished seriously. There was no loss in 1935, due to intensive control measures carried out during the winter of 1934–35. In the

fall of 1935, however, the mealybugs were present in considerable numbers on apple over a much wider area than in 1934. If conditions are favorable for this insect in the future, it may cause heavy losses.

No life history studies were made, but the development appears to be similar to that reported by Hough[1] for this insect in northern Virginia. The overwintered eggs began to hatch about May 10, and hatching was completed about June 15. Second-brood eggs began to hatch early in July, and second-brood adults were present by the end of July. Some of the eggs deposited by the second-brood females hatched during the latter part of August and in early September; but the small number of bugs present in September indicated that the proportion thus hatching was small.

Control.—The problem of control was complicated by the size and the extreme roughness of the bark of the trees, and by the enormous number of eggs present. Every crevice was packed, and the eggs hung in masses from the branches. As it was obvious that no spray could penetrate effectively the masses of ovisacs, the trees were first scraped from the ground up to the smaller branches, and then the crotches and other rough spots were cleaned with wire brushes. When working on the larger trees, a team of two men averaged scraping and brushing five trees per day.

After the bark was scraped, a dormant spray containing 4 per cent of tar oil and 2 per cent of petroleum oil was applied to the trunks and branches. This combined scraping and spray treatment resulted in the removal or the killing of practically all of the eggs. After the application of the spray it was almost impossible to find a living egg. The infestation which developed during the second brood seemed to have come from the eggs left on the smaller branches which were not scraped. The parts of the orchards where the scraping had been less thorough had a greater infestation.

At the time the tar and petroleum oil was applied, a small block of trees was sprayed with a 7 per cent emulsion of kerosene. This spray was less effective than the tar–petroleum, as a light but apparent infestation developed on these trees during the first brood. When the first cover spray was applied May 21, this block was sprayed with nicotine sulfate 1:800. This treatment was repeated in the second cover spray on June 5. The results were satisfactory, as the second-brood infestation in this block was lower than where the tar–petroleum spray was used.

During June and July a 15 per cent emulsion of tar oil was applied with paint brushes to such colonies of the bugs as appeared on the trunks and larger branches. This treatment was very effective, and caused no damage to the trees.

Late in July it was found that there was some infestation in the calyces of the Albemarle Pippins and on the branches of the Winesaps. Immediately a Bordeaux 3–6:100 spray containing nicotine sulfate 1:600 and soap at the rate of 2 pounds per 100 gallons was applied. This gave almost a complete kill of the exposed bugs, but was not more than 50 per cent effective against those within the calyces.

[1] 1925. Va. Ag. Exp. Sta. Tech. Bul. 29.

Some tests of various sprays were carried out on a small scale during August. Nicotine sulfate in dilutions up to 1:800 in combination with either Bordeaux 4–8:100, soap 6 pounds to 100 gallons of water, or penetrol 1:200, was effective against the exposed insects. A derris preparation containing 8 per cent of derris derivatives used at the rate of six pounds to 50 gallons of water, and a .75 per cent rotenone dust also gave promising results. No material was effective against the bugs within the calyces, as many of them could not be reached by a spray.

Summary.—This mealybug caused serious loss in apples in 1934, and must be considered as a dangerous potential pest of this fruit. It was controlled by a dormant spray containing 4 per cent of tar oil and 2 per cent of petroleum oil applied after the trees had been scraped thoroughly and the larger masses of eggs removed. Nicotine sprays applied during the period of the first two cover sprays were also effective. Late-summer applications for the second brood were not satisfactory, because many of the insects were within the calyces where they could not be reached.

PROBLEM OF EUROPEAN RED MITE ON PRUNES IN WESTERN NEW YORK[1]

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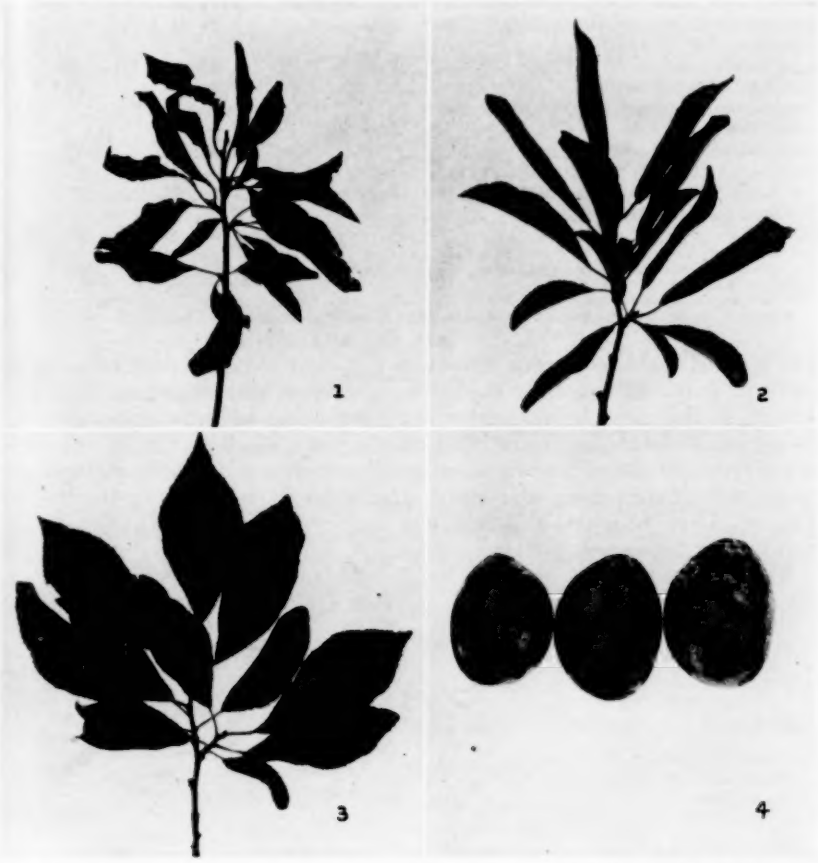
The European red mite, *Paratetranychus pilosus* Can. & Fanz., is probably the most serious pest attacking the prune in western New York. The methods of control practiced by the growers have been the use of a dormant application of a 3 per cent lubricating oil followed by summer sprays of lime sulfur. In recent years, with the development of the wettable sulfur sprays, the tendency has been to apply the dormant oil and follow that with the wettable sulfur as a leaf-spot spray during June and July, in an effort to escape the severe burning due to the use of the lime sulfur, fig. 1. This program has been satisfactory in years when the red mites have not been too serious. However, during hot, dry seasons the mites often increased to such an extent that the foliage has been browned fig. 2, and the fruit dropped prematurely.

With the development of the summer-oil emulsions it was discovered that they were effective in controlling the mites, but the use of the sulfur fungicides thought to be necessary for the prevention of leaf-spot either excluded their use or made it very hazardous. The oil applied either with or closely following a sulfur application usually resulted in severe foliage injury. Moreover, the season of 1934 presented the red mite-control problem more acutely as the severe winter injured the trees to such an extent that it was adjudged unsafe to use the dormant oil. The question arose then as to how to control the red mite and the leaf-spot at the same time.

Experimental work.—Three commercial prune orchards (Italian prunes) in Niagara county were taken over during the 1935 season and

[1] Approved Nov. 27, 1935, by Director of the N. Y. State Agricultural Experiment Station for publication as Journal paper 113.

were treated in various ways. The spraying was done with a regular orchard sprayer carrying about 200–250 pounds pressure. The spraying was done from the ground, the operator walking around the tree and completing each in one operation. The undersides of the leaves as well as the upper were thoroughly wetted. At the time of applying the dormant oil sprays in April the red mite eggs were very scarce and consequently the first-brood population of mites was very low. The rate of infestation was only one mite to 200–300 leaves. The mites hatched soon after the buds opened, and by the time that the blossoms had fallen and the shuck-fall spray was applied, the mites had reached maturity and had begun to oviposit. Normally, in this application the lime sulfur or wettable sulfur is combined with arsenate of lead to prevent attack by plum curculio, this treatment usually being made during the first week of June.



Figs. 1–4.—*Fig. 1*, Prune foliage injured by lime sulfur. *Fig. 2*, Foliage injured by red mites. *Fig. 3*, Normal foliage. *Fig. 4*, Prunes spotted by a summer application of oil.

Table 1.—Intensity of red mite infestation and yield of prunes in relation to various treatments.

Treatment	Date Applied	Average Yield per Tree in ½ Bushel	Number Mites per 50 Leaves July 26
Wettable sulfur 10 lbs. in 100 gals., nicotine sulfate 1:800	June 6	1.92	3160
Dormant oil 3 per cent*†		3.22	774
Bordeaux 2–4:100, nicotine sulfate 1:800	June 6	2.08	3076
Dormant oil 3 per cent*		3	774
Lime sulfur 1:40	June 6	1.61	1456
Dormant oil 3 per cent*		3.03	774
Summer-oil emulsion 6 quarts,‡ Bordeaux 2–4:100	June 6	3.9	10
Dormant oil 3 per cent*		3.5	774
Summer-oil emulsion 6 quarts,‡ Bordeaux 2–4:100, nicotine sulfate 1:2400	June 6	3.53	5
Dormant oil 3 per cent*		3.03	774
Check		1	3950

* Dormant oil followed by two applications of wettable sulfur June 5 and 20, and one of summer oil plus nicotine sulfate 1:2400 July 27.
† Parallels experimental row.
‡ *Orthol K* emulsion (viscosity 65–70, sulfonation test 92–95). California Spray Chemical Corporation.

The second leaf-spot spray was then put on the latter part of June or early in July. At this time the mite population was changing from the second to the third brood and was commencing to show noticeable increase in numbers. From that time on there was no demarcation between broods and all stages were present until fall. When unchecked the mites reached their maximum abundance the latter part of July or the first of August, after which the foliage was so dry and lifeless that the mite population decreased for want of food.

The results of some spraying experiments conducted in a moderately vigorous orchard are presented in table 1. Bordeaux mixture was in-

Table 2.—Red mite control on prunes.

Treatment	Date Applied	Average Yield per Tree in Bushels	Average Number Mites on 100 Leaves July 1	July 23	July 26
Summer oil (*Orthol K Med.*) 6 qts., Bordeaux 2–4:100, nicotine sulfate 1:2400	June 6	2.83	1	6	
Summer oil (*Orthol K Med.*) 6 qts., Bordeaux 2–4:100	June 6	2.87	3	38	
Bordeaux 2–4:100, nicotine sulfate 1:800	June 6	2.8	97	4120	5
Summer oil (*Orthol K Med.*) 6 qts.	July 23				
Wettable sulfur 10 lbs. in 100 gals., nicotine sulfate 1:800	June 6	2.53	43	8126	2
Wettable sulfur 10 lbs. in 100 gals.	June 28				
Summer oil (*Orthol K Med.*) 6 qts., nicotine sulfate 1:2400	July 23				
Lime sulfur* 1:50	June 6	3	6	476	
	June 28				
Check		2.7	89	2440	

* Lime sulfur-sprayed trees larger than others.

cluded on a number of the plats with the summer-oil sprays for protection against leaf-spot which is serious in this area during some seasons. On all the remaining plats the wettable sulfur or lime sulfur served the same purpose. Table 2 gives the results when the same treatments as used in table 1 were applied to a well-cared-for vigorous planting. A comparison between a few brands of summer oil and the dormant-oil treatment is shown in table 3. The effect of the summer oil upon the red mite population is given in table 4.

Table 3.—Red mite control on prunes.

Treatment	Date Applied	Average Yield per Tree in Bushels	Average Number Mites per 100 Leaves July 28
Summer oil* (*Orthol K Med.*) 6 qts. nicotine sulfate 1:2400	June 10	3.6	2
Summer oil (*Superla*) † 5 qts.	June 10	3.25	0
Summer oil (*Superla*) 5 qts., nicotine sulfate 1:2400	June 10	3	3
Summer oil (Stock B)‡ 5 qts.	June 10	3.2	1
Summer oil (Stock B) 5 qts., nicotine sulfate 1:2400	June 10	3.5	3
Dormant oil 3 per cent, *Kolofog* 6 lbs.	June 4	3.16	38
Kolofog 6 lbs.	June 22		
Check		.66	2728

* All summer oils were combined with 2–4:100 Bordeaux.
† Superla oil. Viscosity 80–83, sulfonation test 96–98. Standard Oil Company of Indiana.
‡ Stock B oil was from Sonneborn Oil Company. Viscosity 65–75, sulfonation test 90–94. Stock B tank emulsified with *Goulac*.

Discussion of results.—The data obtained in these experiments bear out more or less the experience of the growers. The dormant-oil treatment is helpful in keeping the red mite population down, but in a hot, dry season it may increase to serious numbers. The lime sulfur is effective in killing the mites, but the burning effect on the foliage is often too severe

Table 4.—Efficiency of summer oil against the red mite.

Treatment	Date Applied	Average Number Mites on 50 Leaves July 26	August 29
Summer-oil emulsion* 6 qts., Bordeaux 2–4:100, nicotine sulfate 1:2400	June 6	6	138
Summer-oil emulsion 6 qts., Bordeaux 2–4:100	June 6	9	333
Summer-oil emulsion 6 qts.	July 23	1	0
Summer-oil emulsion 6 qts., nicotine sulfate 1:2400	July 23	2	1
Check		3950	101

* Summer-oil emulsion = *Orthol K Medium* (83 per cent oil).

and may reduce the yield. The summer oils applied either at the shuckfall spray or later in the summer killed not only the mites but prevented the eggs from hatching. However, when applied in July or August the summer oils, although not actually injuring the fruit, do produce spotting of the prunes, fig. 4, and this detracts from the appearance of the fruit at picking time. When summer oil was applied with Bordeaux at the

shuck-fall stage no spotting was noticeable and the mites did not become numerous. However, they had increased in numbers by September, but since the fruit is usually picked before September 15, and since the foliage at this season is tough and rather dry, the mites produced no noticeable injury. The question still remains as to the fungicidal value of the Bordeaux mixture as a leaf-spot spray since none of this disease was in evidence during the summer of 1935. Continued tests in the future will be necessary to determine this point. From the growers' standpoint the summer oil–Bordeaux mixture is the preferred treatment in that one application takes the place of three required when using the dormant oil–wettable sulfur program. In addition the use of Bordeaux as a fungicide makes it possible to apply a second spray of summer oil at any time without the danger of burning due to the presence of sulfur. Also, as indicated in table 2, it was observed in various plantings that the mites were less numerous on those trees on which no sulfur had been used than on those which had been treated with sulfur sprays or dusts. This was very striking in certain peach orchards. The mites became very abundant on the early peaches, such as South Haven and St. John, when one or two applications of wettable sulfur had been applied for the prevention of brown-rot. In orchards that were not so treated the mites were not observed to become numerous.

The data in tables 1 and 2 suggest that the more vigorous a planting the less is the harmful effects of mite population or lime sulfur. In fact it seems logical to assume that proper fertilization and care of the planting are the first and most important steps in a red mite-control program.

DERRIS INSECTICIDES[1]

VI. SUMMER CONTROL OF EUROPEAN RED MITE ON APPLE WITH DERRIS AND NEUTRAL WETTING AGENTS

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During the summer of 1935 a heavy infestation of European red mite, *Paratetranychus pilosus* Can. & Fanz., on apple was encountered in New Jersey. This increase in population was general throughout the state, and occurred in orchards which had received the regular delayed-dormant oil spray in the early part of the season as well as in orchards which had not received this spray. The increasing intensity of infestation was noted in the early part of July and by the middle of the month many of the trees had become bronzed.

The usual recommendation of the experiment station for red mite control at this time of year is an oil-emulsion spray containing 1 per cent actual oil. At the time of the outbreak in 1935, however, many of the orchards had a deposit of sulfur on the foliage. The presence of this sulfur deposit precluded the use of any oil spray for the control of red mite

[1] Paper of the Journal series, New Jersey Agricultural Experiment Station, Department of Entomology.

because of injury resultant from any oil–sulfur combination. In response to inquiries concerning a spray with which to control this pest under these conditions, investigation was undertaken to determine if derris might be used in this capacity.

In the consideration of derris as a contact spray it was necessary to choose a suitable wetting agent. It was not deemed advisable to consider soap because of the possibility of injury to the foliage when a deposit of lead arsenate was present. The work of Ginsburg (*2*) and of Cory & Langford (*1*), has indicated the value of neutral wetting agents, of which there are a number on the market. Accordingly it was decided to test combinations of derris and certain neutral wetting agents as a control for the European red mite under the existing conditions.

The experiment was suggested by Dr. T. J. Headlee and was conducted under the direct supervision of Dr. J. M. Ginsburg.

Table 1.—Tests on European red mite on apple. Orchard No. 1, application No. 1, July 27, 1935.

Spray	No. of Leaves	No. of Mites			Per Cent Kill
		Dead	Alive	Total	
Derris dust (1% rotenone) 10 lbs., *Aresket* 10 oz. to 100 gals.	10	143	75	218	66
Derris dust (1% rotenone) 10 lbs., *Aresklene* 10 oz. to 100 gals.	10	48	6	54	89
Derris dust (1% rotenone) 15 lbs., *Aresklene* 10 oz. to 100 gals.	10	52	6	58	90
Derris dust (1% rotenone) 5 lbs., *Areskap* 10 oz. to 100 gals.	25	440	33	473	93
Derris dust (1% rotenone) 10 lbs., *Areskap* 10 oz. to 100 gals.	10	231	10	241	91
Derris dust (1% rotenone) 15 lbs., *Areskap* 10 oz. to 100 gals.	10	223	29	252	88.5

Tests in the college orchards.—An opportunity for testing the above-mentioned combinations on red mite presented itself when a heavy infestation was reported in orchards Nos. 1 and 2 of the Department of Horticulture at the New Jersey Experiment Station, New Brunswick. In cooperation with the Department of Horticulture, experimental work was started in orchard No. 1. The orchard was divided into six blocks, each block to be sprayed with a different combination of derris and a neutral wetting agent.

In these sprays the derris was supplied in the form of a prepared dust containing 1 per cent rotenone, and was used at three different concentrations—5, 10 and 15 pounds to 100 gallons of spray. Three neutral wetting agents, known commercially as *Aresket*, *Areskap* and *Aresklene*,[2] were used, each at the concentration of 10 ounces to 100 gallons. These materials were selected for the experiment because previous tests conducted by the writer and others have shown them to be highly efficient as wetting and spreading agents with insecticides and fungicides, as well as being noninjurious to foliage. Chemically, they are neutral salts of sulfated butyl diphenyl compounds, practically free from sodium sulfate. These sprays were applied by the regular spray crew with a power sprayer

[2] These neutral wetting agents were obtained from the Monsanto Chemical Company, St. Louis, Mo.

on July 26. Twenty-four hours after application, random leaf samples were taken in the blocks and examined for live and dead mites.

The spray combinations used, and the results of the count are shown in table 1.

These results indicate that 5 pounds of derris dust (1 per cent rotenone) per 100 gallons was as effective as 10 or 15 pounds per 100 gallons. There did not appear any significant difference in the effectiveness of *Aresklene* or *Areskap* as wetting agents. As *Aresklene* is a more expensive product than *Areskap* it was dropped from consideration. The one spray using *Aresket* was not as satisfactory as any of the others, but the author observed that it did not receive as thorough an application as did the others, so it was deemed advisable to give *Aresket* a further trial.

Examination of the leaves showed that the sprays had no ovicidal effect. Larvae hatching soon after the spray had dried were apparently unaffected by the residue on the leaves. Because of this it was found necessary to apply two sprays to effect control, the second spray to follow

Table 2.—Tests on European red mite on apple. Orchard No. 1, application No. 2, August 8, 1935.

Spray	No. of Leaves	No. of Mites			Per Cent Kill
		Dead	Alive	Total	
Derris dust (1% rotenone) 5 lbs., *Aresket* 8 oz. to 100 gals.	26	426	85	511	83.5
Derris dust (1% rotenone) 10 lbs., *Aresket* 8 oz. to 100 gals.	25	153	38	191	80
Derris dust (1% rotenone) 5 lbs., *Areskap* 8 oz. to 100 gals.	25	164	50	214	76.5
Derris dust (1% rotenone) 10 lbs., *Areskap* 8 oz. to 100 gals.	26	241	36	277	87

the first application by a period of one week so that most of the eggs would have hatched but none of the nymphs would have reached maturity. When climatic factors retard the development of the immature stages, the one-week interval may be lengthened up to two weeks, depending on the rate of development shown by the larvae and nymphs.

At the same time as the application of the sprays, one row of trees was dusted with the derris dust of 1 per cent rotenone content. Examination showed that the dust had little effect on the red mites. The failure of the dust application was so obvious that no detailed count was made on leaf samples.

On August 2, one week after the first application, the same orchard was sprayed again. This time the orchard was divided into four blocks. Derris dust of 1 per cent rotenone content was used at the rates of 5 and 10 pounds per 100 gallons. *Aresket* and *Areskap* at the rate of 8 ounces to 100 gallons were used as wetting agents. The counts were made as in the previous test. The spray combinations and the results of the counts are shown in table 2.

The results indicate that there was little difference in the effectiveness of the sprays. Five pounds of derris dust (1 per cent rotenone) to 100 gallons appeared as effective as 10. *Aresket* in these sprays was as satisfactory as *Areskap* as a wetting agent.

As these sprays were giving satisfactory control, it was decided to spray orchard No. 2 on the horticultural farm with the same materials. On August 6 the orchard was sprayed. It was divided into two blocks. Both blocks received a spray containing 10 pounds of derris dust (1 per cent rotenone) to 100 gallons. In one spray, *Aresket* at 8 ounces to 100 gallons was used as a wetting agent, while in the other spray *Areskap* at same rate performed this function. The counts were made at the end of 24 hours as before and the results are shown in table 3.

Table 3.—Tests on European red mite on apple. Orchard No. 2, application No. 1, August 6, 1935.

Spray	No. of Leaves	No. of Mites			Per Cent Kill
		Dead	Alive	Total	
Derris dust (1% rotenone) 10 lbs., *Aresket* 8 oz. to 100 gals.	50	359	133	492	73
Derris dust (1% rotenone) 10 lbs., *Areskap* 8 oz. to 100 gals.	50	429	135	564	76

The results show no significant difference between the values of *Aresket* and *Areskap* as wetting agents in these sprays. They also show that these sprays were not as effective as the applications in orchard No. 1. The author observed that the application of this spray was not as thorough as those applied previously, and also that the second application in orchard No. 1 was not as thorough as the first application. This was due to changes in the personnel of the spray crew. This was also confirmed by a check on the amount of materials being used. This fault was eliminated in the next application.

Table 4.—Tests on European red mite on apple. Orchard No. 2, application No. 2, August 19, 1935.

Spray	No. of Leaves	No. of Mites			Per Cent Kill
		Dead	Alive	Total	
Derris dust (1% rotenone) 5 lbs., *Aresket* 8 oz. to 100 gals.	35	106	47*	153	69*
Derris dust (1% rotenone) 7½ lbs., *Aresket* 8 oz. to 100 gals.	35	127	12	139	92
Derris dust (¾% rotenone) 5 lbs., *Aresket* 8 oz. to 100 gals.	39	119	18	137	87
Derris dust (¾% rotenone) 7½ lbs., *Aresket* 8 oz. to 100 gals.	56	128	11	139	92
Derris dust (1% rotenone) 5 lbs., *Aresket* 12 oz. to 100 gals.	35	171	2	173	99
Derris dust (1% rotenone) 7½ lbs., *Aresket* 12 oz. to 100 gals.	45	129	5	134	96
Derris dust (¾% rotenone) 5 lbs., *Aresket* 12 oz. to 100 gals.	44	153	7	160	96

* Thirty-six of the 47 alive mites were on three leaves which had apparently been missed in spraying.

The second application in orchard No. 2 was made on August 19. For this spray the orchard was divided into seven blocks. Two types of derris dust were used, one containing three-fourths per cent rotenone and the other 1 per cent rotenone. *Aresket* was used as the wetting agent at two concentrations, 8 and 12 ounces to 100 gallons. The counts were made

as in other tests. The spray combinations and results of the counts are shown in table 4.

The differences shown among these results are not great enough or uniform enough to permit any significance to be attached to them.

Average infestation before sprays were applied in these orchards was approximately 1000 mites to 100 leaves. On August 29, 10 days after the last spray was applied in orchard No. 2 and 27 days after the last application in orchard No. 1, an examination was made of 100 leaf samples taken at random from each orchard. On 100 leaves from orchard No. 1, 12 mites were found. This constituted approximately 99 per cent control.

Table 5.—Tests on European red mite on apple. Dayton, N. J., September 10, 1935.

Spray	No. of Leaves	No. of Mites			Per Cent Kill
		Dead	Alive	Total	
Derris dust (1% rotenone) 5 lbs., *Aresket* 8 oz. to 100 gals.	16	182	57	239	76
Derris dust (1% rotenone) 7½ lbs., *Aresket* 8 oz. to 100 gals.	28	198	63	261	76
Derris dust (1% rotenone) 5 lbs., *Aresket* 12 oz. to 100 gals.	19	189	29	218	87
Derris dust (1% rotenone) 7½ lbs., *Aresket* 12 oz. to 100 gals.	10	186	20	206	90
Derris dust (1% rotenone) 7½ lbs., skim milk 1 lb. to 100 gals.	10	138	59	197	70
Derris root (4% rotenone) 1¼ lbs., *Aresket* 8 oz. to 100 gals.	7	228	29	257	89
Derris root (4% rotenone) 2 lbs., *Aresket* 8 oz. to 100 gals.	10	219	17	236	93
Derris root (4% rotenone) 1¼ lbs., *Aresket* 12 oz. to 100 gals.	10	410	33	443	93
Derris root (4% rotenone) 2 lbs., *Aresket* 12 oz. to 100 gals.	10	468	77	545	86
Derris root (4% rotenone) 2 lbs., skim milk 1 lb to 100 gals.	10	189	109	298	63

On 100 leaves taken from orchard No. 2, 25 mites were found, indicating approximately 97.5 per cent control.

Although no check blocks were run with each test, two trees near the edge of orchard No. 1 were not sprayed. Examination on August 29 showed an average population of approximately 1500 mites on 100 leaves. This indicates that natural factors would not be responsible for the control obtained and the control should be fully ascribed to the treatment.

The diluent material of the dusts proved to be somewhat objectionable in these sprays. This clay remained as a deposit on the apples. Much of it washed off during the season but at picking time traces were found in the form of spots around the calyx end of the apple.

Tests in Dayton orchard.—Early in September a heavy infestation of red mite in an orchard at Dayton, N. J., was reported. Further experiments were carried out in this orchard. It was not convenient to use a power sprayer for this work, and so the spraying was done with a knapsack sprayer. One branch on a tree was selected and all the foliage on

this branch sprayed. Leaves selected at random from the sprayed branches were examined 24 hours after spraying.

All the tests to this time had used derris in the form of a diluted dust containing 1 per cent or three-fourth per cent rotenone. It was considered advisable, because of the objection to the diluent material of the dust, to determine if a finely ground undiluted derris root yielding the same amount of rotenone per unit of spray would be as effective. A finely ground derris root containing 4 per cent rotenone was used for this purpose. As skim milk is a cheap and commonly used spreading agent, it was decided to test it at the rate of 1 pound to 100 gallons in comparison with *Aresket* at 8 and 12 ounces to 100 gallons. Ten different sprays were

Table 6.—Tests on European red mite on apple. Dayton, N. J., September 13, 1935.

Spray	No. of Leaves	No. of Mites			Per Cent Kill
		Dead	Alive	Total	
Derris root (4% rotenone) 1¼ lbs., *Aresket* 10 oz. to 100 gals.	10	759	0	759	100
Derris root (4% rotenone) 2 lbs., *Aresket* 10 oz. to 100 gals.	16	941	4	945	99
Derris root (4% rotenone) 1¼ lbs., skim milk 2 lbs. to 100 gals.	13	509	71	580	88
Derris root (4% rotenone) 2 lbs., skim milk 2 lbs. to 100 gals.	11	595	99	694	86
Derris root (4% rotenone) 1¼ lbs., to 100 gals. plus .2% actual soap	13	492	7	499	99
Derris root (4% rotenone) 2 lbs. to 100 gals. plus .2% actual soap	12	595	11	606	98

applied on September 10. Seven hours after the application of the first spray and one-half hour after that of the last spray, a heavy rain fell.

The spray combinations and the results of counts on random leaf samples are shown in table 5.

From these results it can be seen that the derris root of 4 per cent rotenone content gave better kill than did the 1 per cent derris dust when used so as to give equal rotenone content per unit of spray. There also was a tendency for the 12 ounces of *Aresket* per 100 gallons to produce better kill than the 8 ounces of *Aresket* per 100 gallons. The smaller amount of derris gave as good kill as the greater amount.

In order to compare further the efficiency of *Aresket* as a wetting agent with that of skim milk, and to include a comparison with soap, six more tests were carried out on September 12. In these only derris root of 4 per cent rotenone content was used. This was used at two concentrations. *Aresket* at 10 ounces to 100 gallons, skim milk at 2 pounds to 100 gallons, and coconut-oil soap at .2 per cent of actual soap were used as wetting agents. The counts were made as previously described. The spray combinations and the results of the counts are shown in table 6.

This test showed no difference between the effectiveness of *Aresket* at 10 ounces to 100 gallons and that of soap at .2 per cent. Both, however, were shown to be superior to skim milk at 2 pounds to 100 gallons when used for this purpose. *Aresket*, therefore, was the most satisfactory wetting agent for this spray, as it compared favorably in cost with soap and

was compatible with lead arsenate. No difference was observed in the effectiveness of the two amounts of derris root.

Summary and conclusions.—Field tests were carried out on the summer control of European red mite on apple trees the foliage of which retained sulfur and arsenical residues. Sprays containing derris in various proportions in combination with different wetting agents were used. Derris was supplied in three forms, a dust of 1 per cent rotenone content, a dust of three-quarters per cent rotenone content, and a finely ground root of 4 per cent rotenone content. *Aresket*, *Areskap*, *Aresklene*, skim milk and soap were used as wetting agents. The combination which was shown to be most satisfactory consisted of $1\frac{1}{4}$ to 2 pounds of derris root (4 per cent rotenone) and 10 ounces of *Aresket* or *Areskap* to 100 gallons of spray. The outstanding feature of this spray, beyond its toxicity to the pest, was its compatibility with sulfur and lead arsenate deposits on the foliage, the presence of the former precluding the use of any oil spray, and the presence of the latter estopping the use of any spray containing soap. Two applications spaced at a period of from one to two weeks apart were necessary to effect control. The length of period between applications was dependent on the rate of development of the immature stages of the mite. Thorough application was found to be essential for the effective use of this spray.

Derris dust of 1 per cent rotenone content was of no value in the control of this pest when applied as a dust.

Literature Cited

(*1*) **Cory, E. N.** and G. S. Langford. 1935. Sulfated alcohols in insecticides. Jour. Econ. Ent. **28**(2): 257. Apr.

(*2*) **Ginsburg, J. M.** 1935. New wetting agents for old insecticides. Jour. Econ. Ent. **28**(1): 224. Feb.

TAR-OIL AND LUBRICATING-OIL SPRAYS IN RELATION TO ROSY APHID CONTROL AND TO WINTER-INJURED TREES[1]

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Climatic conditions in western New York during 1933 and 1934 and the effects on fruit trees have been briefly discussed in a previous publication.[2] The present paper presents the results of a series of tests with tar-oil and lubricating-oil sprays applied during the spring of 1935 to determine their relative insecticidal efficiencies on the rosy aphid, *Anuraphis rosae*, and their effects on apple trees which had a single growth period following a severe winter.

Materials.—An effort was made to use all the commercial brands of tar distillate, tar–lubricating oil, and lubricating oil–cresylic acid-

[1] Approved Dec. 30, 1935, by the Director of the New York State Agricultural Experiment Station for publication as Journal paper 117.

[2] **Hartzell, F. Z.,** S. W. Harman, and T. W. Reed. 1935. Some recent developments in regard to tar-distillate and tar–lubricating-oil sprays. Jour. Econ. Ent. **28**(2): 263–8. Apr.

emulsions on the market. A number of commercial lubricating-oil emulsions were used with nicotine, also tank-mixed emulsions including all these various ingredients were applied. In addition, water-gas tar oil having a boiling range similar to straight-run creosote oil (as defined in the paper cited above) was tested on a few trees both alone and with lubricating oil. Incidentally it should be mentioned that at present all the brands of tar-distillate emulsions studied contain no lubricating oil and all the tar–lubricating-oil emulsions contain the two oils in the proportion of 2.4 to 3. The various brands and tank mixtures are designated by a number in table 1 to show which trees were treated with the same mixtures. Owing to the small number of trees used in each case and the many varieties involved, unfair comparisons might be made if brand names were given. In a previous paper[3] tentative dilutions were given for various insects. The experiments of 1935 provided the first opportunity for further proving the validity of these tentative concentrations as well as for corroborating certain conclusions there suggested.

Nature of the experiments.—The apple trees used for the field trials were in one of the station orchards that was set in 1898, but a number of the trees were replacements of a somewhat later date. For these tests 67 trees consisting of 52 varieties were used. With the exception of two trees in which the tops were divided into thirds, each received a treatment on one half of the top while the other half was left untreated for comparison. It was planned with each class of mixture to have about equal numbers of sprayed halves facing the four cardinal points of the compass in order to compensate for variation due to position. This was found to be impractical due to the scarcity of days with good spraying weather and suitable ground conditions. It was necessary to treat the leeward side to avoid spray drift so that the location of the treatment depended on direction of the wind. Six trees neither bloomed nor were infested with aphids sufficiently to secure reliable information. This left 61 trees consisting of 43 known and three unknown varieties for which data are given. The percentage of fruit set on the sprayed portion of a tree was compared with the percentage of fruit set on the untreated part of the same tree. By this method information was secured on varieties, each represented by only a single tree in the orchard. Even where there were several trees of the same variety, the half-top method eliminated variation in infestation and especially differences in degree of winter injury between individual trees.

Spraying was done with modern machinery maintaining pressures between 350 and 400 pounds at the pressure chamber. A spray gun was used, the operator being on the ground. All mixtures containing creosote oil or water-gas tar oil were applied before the most advanced buds had reached the silver-tip stage. Counts of fruitlets and scars of blossom pedicels were made in June. All fruitlets that dropped or were ready to drop at that time were classed as blossoms that had not set fruit. Data on rosy aphid infestation were secured by counting infested leaf clusters in early July. The results are presented in table 1, following.

[3] Hartzell, F. Z., and G. W. Pearce. 1934. Tentative standard concentration of tar distillates for certain insects. Jour. Econ. Ent. 27(2):453–9. Apr.

Discussion.—As regards the rosy aphid, the data in table 1 appear to justify the following inferences which in turn tend to support conclusions previously drawn.

Table 1, Part I.—Data of tar-oil and lubricating-oil treatments on rosy aphid control and effects on different varieties of apple trees.

Variety	Vigor of Tree	Fruit Set† *Per Cent Gain (+) Loss (−)*	Half of Tree Sprayed	Brand or Mixture	Control Efficiency on Rosy Aphid‡
		Creosote Oil 2.4 Per Cent			
Sierra Beauty	W*	+38	SE	VII	100
Florence	W	+ 9	W	VI	
Sierra Beauty	W	+ 8	W	IV	92.5
Hubbardston	W	− 2	W	II	95.2
King David	W	−33	W	VIII	95.2
R. I. Greening	W	−36	SE	III	98.1
Wagener	W	−37	W	V	
Westchester	W	−61	S	VII	83.3
Fost Prize	MV	−72	S	III	96.8
Axident	W		W	IV	100
Becker	W		W	I	100
Becker	W		W	II	96.9
Hackworth	W		W	I	100
Lady	W		W	V	100
R. I. Greening	W		W	VIII	98.5
Average					*96.7*
		Creosote Oil 4.5 Per Cent			
Westchester	W	+34	W	V	
Superba	MV	+16	W	IV	100
Giant Jeniton	MV	+11	S	VII	100
Knepper	MV	− 4	S	VIII	100
Scarlet Beauty	MV	−11	W	V	92.7
Early Goodman	W	−21	W	VI	100
Starr	MV	−30	S	I	96.2
Wealthy	W	−32	W	VII	
Orenco	MV	−35	W	II	100
Wheeler	W	−43	W	V	100
Unknown	MV	−56	W	V	100
Arkansas	W		W	IV	100
Crow Egg	W		S	I	100
Frost Prize	W		W	III	100
Geiger	W		W	V	85
Hubbardston	W		S	VIII	100
Superba	MV		W	III	87.5
Average					*97.4*
		Creosote Oil 2.2 Per Cent Plus Lubricating Oil 2.8 Per Cent			
Peerless	V	0	S	XII	96.4
Peerless	V	− 5	S	X	95
Sir John Thornycroft	V	−11	S	XIII	100
McIntosh	MV	−14	S	IX	100
Esopus	MV	−15	S	XII	100
British Columbia	MV	−23	S	XIV	91.8
Unknown	V	−25	S	XIV	98.8
Bailey	MV	−35	S	X	85.8
Myrick	MV	−45	S	XI	87.2
Fanny	MV	−77	S	XIII	99
Twenty Ounce	V		S	IX	95
Average					*95.4*
		Water-gas Tar Oil 2.4 Per Cent			
R. I. Greening	W	− 4	W	XV	87.2
Montgomery	W		W	XV	89.2
Average					*88.2*

* W = weak, MV = moderately vigorous, and V = vigorous.
† Vacancies in this column mean no blossoms due to lack of buds, not to material used.
‡ Vacancies in this column mean an insufficient number of aphids or none in the untreated half.

A concentration of 2.4 per cent of creosote oil appears to be a practical amount to secure a high degree of control.

In a tar–lubricating-oil spray the toxic effects on aphid eggs apparently depend entirely upon the concentration of creosote oil and are not increased by the lubricating oil present, at least when the latter does not exceed 3 per cent.

The similar results secured, at the same dilutions of creosote oil, with all commercial brands and with tank-mixed emulsions, indicate that either all the manufacturers have used creosote oil which meets the standards proposed in 1934 or that the differences are not sufficient to affect the control of the aphid.

Water-gas tar oil with a boiling range similar to that of creosote oil apparently has rather high ovicidal value against the rosy aphid. Because of the light aphid infestation during 1935 and lack of critical tests on bud moth, sufficient data are not available to determine whether or not water-gas tar oil can be substituted for creosote oil at the same concentration.

Cresylic acid in lubricating oil applied during the early green-tip stage gave more variable control than did creosote oil. Similar results have been secured in more extended tests during the past six years. Not-

Table 1, Part II.—Data of tar-oil and lubricating-oil treatments on rosy aphid contol and effects on different varieties of apple trees.

Variety	Vigor of Tree	Fruit Set† *Per Cent Gain (+) Loss (−)*	Half of Tree Sprayed	Brand or Mixture	Control Efficiency on Rosy Aphid‡
		Water-gas Tar Oil 4.5 Per Cent			
Andersleber Calville	W*	+32	S	XV	90.9
Hubbardston	MV		S	XV	100
Average					*95.5*
		Water-gas Tar Oil 2.2 Per Cent Plus Lubricating Oil 2.8 Per Cent			
Constantine	V	+15	E	XVI	
Sir John Thornycroft	MV	+13	E	XVI	98.1
		Lubricating Oil 3 Per Cent Plus Cresylic Acid .5 Per Cent			
Wagener	MV	+12	E	XVII	100
Rome	W	− 7	E	XVII	89
Orenco	W	−29	E	XVIII	53.3
Baldwin	MV		E	XVIII	100
Average					*85.6*
		Lubricating Oil 3 Per Cent Plus Nicotine Sulfate 1:800			
Collins	W	+25	E	XIX	36
Deacon Jones	MV	−10	E	XX	100
British Columbia	MV	−31	E	XIX	100
Winter Banana	W		E	XX	92.4
Average					*82.1*
		Lubricating Oil 3 Per Cent Plus Nicotine Sulfate 1:400			
Winter Banana	MV	+37	E	XXI	100
Unknown	MV	+15	E	XXII	
Jonathan	W	−49	E	XXI	94.6
Kinnard	W		E	XXII	100
Average					*98.2*

* W = weak, MV = moderately vigorous, and V = vigorous.
† Vacancies in this column mean no blossoms due to lack of buds, not to material used.
‡ Vacancies in this column mean an insufficient number of aphids or none in the untreated half.

withstanding its defects, cresylic acid and lubricating oil may have a place in the spray program, as shown later.

Nicotine sulfate, 1:800 in 3 per cent lubricating oil, applied during the green-tip stage, gave results similar to cresylic acid and oil. When used at a concentration of 1:400 excellent control was obtained. These results are similar to those secured in more extensive field tests during the past four years and indicate that these mixtures may help to extend the period for rosy aphid control.

As regards the relation of oil injury by application in 1935 to trees injured by low temperature during February 1934, the following facts appear to have been determined:

It should be stated that in 1934 a number of these same trees were

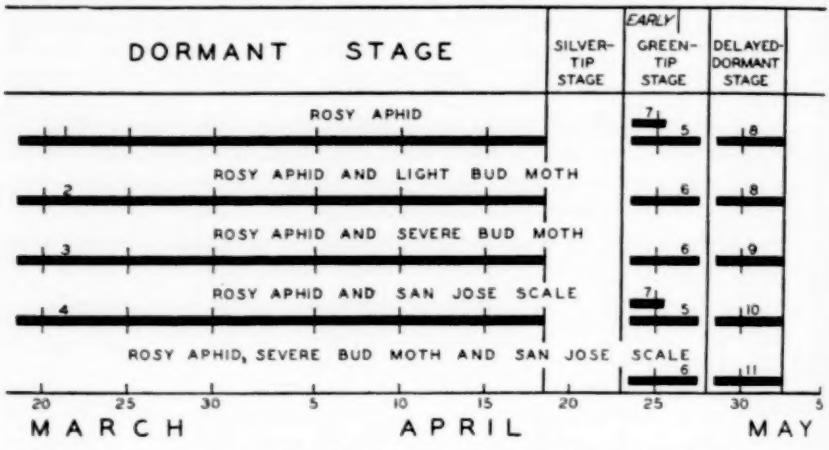

Fig. 1.—Stages of apple buds and period for application of various spray mixtures to control rosy aphid, bud moth and San Jose scale. The materials, based on 100 gallons of spray mixture and represented by numbers, are as follows: (1) creosote oil 2.4 gals., (2) creosote oil 3 to 4 gals., depending on amount of infestation, (3) creosote oil 4.5 gals., (4) creosote oil 2.4 gals. and lubricating oil 3 gals., (5) lubricating oil 3 gals. and nicotine 1 pint, (6) lubricating oil 3 gals. and nicotine 1 quart, (7) lubricating oil 3 gals. and cresylic acid one-half gal., (8) lime sulfur 2½ gals., and nicotine 1 pint, (9) lime sulfur 2½ gals. and nicotine 1 quart, (10) lime sulfur 11 gals. and nicotine 1 pint, (11) lime sulfur 11 gals. and nicotine 1 quart.

sprayed with creosote oil, lubricating oil or a combination of both oils, and considerable twig injury resulted where the concentrations were in excess of 3 per cent. Since no twig injury occurred in 1935, at similar concentrations, apparently the trees tolerated heavier dosages in 1935 than in 1934.

There were indications of an increase in the set of fruit on some trees, although generally the number with each treatment is so small that these may have been chance results or may have been due to other factors. There are also indications that all the oil preparations reduced set of fruit on some trees. The proportion of such trees increased with the increase in oil concentration, even though an effort was made to graduate

the dosage somewhat, according to the apparent vigor of the trees. With some exceptions the treatments did not cause serious losses in set of fruit.

Judged by the amount of terminal growth produced in 1934, apparently the vigor of trees, previously exposed to adverse climatic conditions does not give a true indication of their ability to tolerate various dilutions of creosote or lubricating oils. There was a rather marked difference in varieties as regards effects of oils.

Apparently creosote oil and lubricating oil, when either was used alone, were quite similar in their effects on set of fruit.

Water-gas tar oil appears to have been less toxic to the fruit buds than creosote oil when both were used at the same concentration.

Combined sprays for rosy aphid and other insects.—In New York the eye-spotted bud moth, *Spilonota ocellana*, is normally present in numerous orchards, and San Jose scale, *Aspidiotus perniciosus* is of considerable economic importance in many localities. When either or both these insects are present it is desirable to use spray mixtures that will be effective against the rosy aphid and will control either or both of these pests. This serves to economize labor and time. Since the number of days suitable for spraying are usually limited during the spring in New York, any time-saving factor which will enable fruitgrowers to use the more propitious days for treatment should result in better control. The graph, fig. 1, shows the stages of the apple buds during periods when the several mixtures should be applied and the average dates during the past five years when these conditions were found at Geneva, N. Y. The graph begins at March 19, the average date when the first dormant treatments were applied in the spring. Furthermore, the various mixtures found efficient for the control of the rosy aphid, either alone or when present with the bud moth or San Jose scale, are given.

FURTHER STUDIES OF LARVICIDES TO CONTROL FRUIT TREE LEAF ROLLER

WITH SPECIAL REFERENCE TO LEAD ARSENATE AND SUPPLEMENTS[1]

P. J. CHAPMAN and R. W. DEAN, *New York State Agricultural Experiment Station, Geneva*

During the past two seasons, the writers have had occasion to conduct experiments on the control of the fruit tree leaf roller, *Cacoecia argyrospila* Walker. These and future studies have as their objective a reevaluation of the control measures that have been proposed by earlier investigators and which serve as the basis for present recommendations to orchardists. Particular attention is being given to the rather neglected possibilities of combating the pest in the larval stage. A report of the

[1] Approved Jan. 6, 1936, by the Director of the New York State Agricultural Experiment Station for publication as Journal paper 119.

Table 1, Part I.—Results of some of the treatments tested for the control of the fruit tree leaf roller in 1935 at Fishkill, N. Y.

Plat No.	Schedule of Treatments and Materials per 100 Gallons				Total Examined		Average No. Fruits per Tree		Yield Reduced Per Cent	Picked and Drop Fruit Injured, Per Cent, Based on		Control Efficiency Per Cent Based on	
	Dormant Spray	Pre-blossom Sprays—Dates		Calyx and 7-day Sprays	Trees	Fruits	Actual	Theoretical	(No. 1)	Actual Yield (No. 2)	Theoretical Yield (No. 3)	No. 2	Nos. 1 & 3
1	8% oil	LS* only	5/2	Same as Pre-blossom	6	12,434	2,072	3,999	48.2	23.2	11.6	68.4	33.8
2	6% oil	LS only	5/2	Same as Pre-blossom	11	42,532				17.6	14.1	76	65.6
4	6% oil	LA 3 lbs., LS	4/30	Same as Pre-blossom	3	13,969	3,901	4,701	17	10.6	10.6	85.6	69.5
3	6% oil	LA 6 lbs., LP ½ lb., WS	4/30	Same as Pre-blossom	5	20,071				10.6	8.7	85.6	71.6
5	6% oil	LA 6 lbs., Min. oil .5%, CAS	4/29	Same as Pre-blossom	3	8,630				8	6.2	89.1	74.3
6	None	LA 3 lbs., LS	4/30	Same as Pre-blossom	3	12,232	4,077	4,414	7.6	43.3	40.7	28.4	50.7
7	None	LA 6 lbs., LS	4/30	Same as Pre-blossom	5	23,016	4,604	4,583	0	28	28	53.7	66.1
8A	None	LA 6 lbs., LP ½ lbs., LS	4/30	Same as Pre-blossom	3	14,277				29.6	29.6	51.1	64.2
8B	None	LA 6 lbs., LP ½ lb., LS	4/30, 5/7	Same as Pre-blossom	2	9,626	4,781	4,440	0	24.2	24.2	60	70.7
8X	None	LA 6 lbs., LP ½ lb., LS	4/30	LS only	2	6,912	3,456	4,937	30	42.6	30	29.6	27.3
10A	None	LA 3 lbs., LP ½ lb., WS	4/29, 5/7	Same as Pre-blossom	2	7,089				33.4	32.9	54.5	61.8
10B	None	LA 3 lbs., LP ½ lb., WS	4/29, 5/2, 5/7	Same as Pre-blossom	4	22,002	4,858	4,937	1.6	24.9	24.5	66.1	71.1
11A	None	LA 6 lbs., LP ½ lb., WS	4/29, 5/7	Same as Pre-blossom	6	30,357				13.7	13.7	81.3	84.8
11B	None	LA 6 lbs., LP ½ lb., WS	4/29, 5/2, 5/7	Same as Pre-blossom	3	12,142	4,723	4,414	0	13.4	13.4	81.7	85.2
11X	None	LA 6 lbs., LP ½ lb., WS	4/29, 5/7	LS only	5	16,314	3,263	4,335	24.7	55.3	41.4	24.7	26.9
12	None	LA 6 lbs., LP ½ lb., NS 1 pt., WS	4/30, 5/8	Same as Pre-blossom	6	23,419	3,903	4,256	0	10.8	10.8	85.3	88
12X	None	LA 6 lbs., LP ½ lb., NS 1 pt., WS	4/30, 5/8	LS only	1	4,078	4,078	3,890	0	33.8	33.8	54	62.6
22	None	LA 6 lbs., Min. oil .5%, WS	5/1	Same as Pre-blossom	8	26,585	3,323	3,524	0	12.8	12.8	82.6	85.8
14A	None	LA 6 lbs., Min. oil .5%, CAS	4/29, 5/6	Same as Pre-blossom for plat 22	7	30,605				13.4	13.4	81.7	85.2
14B	None	LA 6 lbs., Min. oil .5%, CAS	4/29, 5/1, 5/7		3	8,707	3,816	3,999	0	9.7	9.7	86.8	89.3
14D	None	LS only	5/2		3	10,302				11.8	11.8	83.9	86.9
14X	None	LA 6 lbs., Min. oil .5%, CAS	4/29, 5/6	LS only	2	3,825	1,912	2,817	32.1	66.5	47.2	9.5	12.3
16	None	LA 3 lbs., Min. oil .5%, CAS	4/29, 5/6	Same as Pre-blossom	5	15,809	3,162	3,314	0	13.3	13.3	81.9	85.3
20A	None	LA 3 lbs., Fish oil 1 qt., WS	4/29	Same as Pre-blossom	3	11,884	3,961	5,024	21.1	39.6	33.9	46.1	39.2
20B	None	LA 3 lbs., Fish oil 1 qt., WS	4/29, 5/6	Same as Pre-blossom	2	11,270	5,635	6,734	16.3	34.5	28.3	53.1	50.6
20X	None	LA 3 lbs., Fish oil 1 qt., WS	4/29	LS only	2	7,557	3,778	6,429	41.2	69.9	36.4	4.9	14.2
18	None	LA 6 lbs., Fish oil 1 qt., WS	4/29	Same as Pre-blossom	3	9,881	3,294	3,314	0	18.4	18.4	74.9	79.6
18X	None	LA 6 lbs., Fish oil 1 qt., WS	4/29	LS only	1	2,766	2,766	3,524	21.5	62.1	48.7	15.5	22.3
21A	None	LA 3 lbs., Pine-tar soap 1 lb., WS	4/29	Same as Pre-blossom	3	12,145				38.9	38.9	47	56.9
21B	None	LA 3 lbs., Pine-tar soap 1 lb., WS	4/29, 5/2	Same as Pre-blossom	1	5,942	4,042	4,021	0	35.6	35.6	51.5	60.6
21X	None	LA 3 lbs., Pine-tar soap 1 lb., WS	4/29, 5/2	LS only	2	6,340	3,170	5,408	41.4	71.6	42.1	2.6	7.6
19A	None	LA 6 lbs., Pine-tar soap 1 lb., WS	4/29	Same as Pre-blossom	2	6,103	3,304	3,890	0	20.6	20.6	71.9	77.2
19B	None	LA 6 lbs., Pine-tar soap 1 lb., WS	4/29, 5/6	Same as Pre-blossom	1	3,810				15.3	15.3	79.2	83.1
19X	None	LA 6 lbs., Pine-tar soap 1 lb., WS	4/29	LS only	1	3,626	3,626	5,329	31.9	57	39.2	22.4	21.3
30	None	LA 6 lbs., Rosin fish-oil soap 3 lbs., WS	4/29, 5/2	Same as Pre-blossom	8	30,490	3,811	4,544	16.1	56.6	44.5	6.4	26.6‡
25B	None	Coated LA 12 lbs., WS	4/29, 5/2	Same as Pre-blossom	1	4,988	5,649	4,780	0	21.1	21.1	71.3	76.6

Table 1, Part II.—Results of some of the treatments tested for the control of the fruit tree leaf roller in 1935 at Fishkill, N. Y.

Plat No.	Schedule of Treatments and Materials per 100 Gallons				Total Examined		Average No. Fruits per Tree		Yield Reduced Per Cent	Picked and Drop Fruit Injured, Per Cent, Based on		Control Efficiency Per Cent Based on	
	Dormant Spray	Pre-blossom Sprays—Dates		Calyx and 7-day Sprays	Trees	Fruits	Actual	Theoretical	(No. 1)	Actual Yield (No. 2)	Theoretical Yield (No. 3)	No. 2	Nos. 1 & 3
25D	None	Coated LA 12 lbs., WS	4/29, 5/2, 5/8	Same as Pre-blossom	1	6,309				21	21.1	71.3	76.7
25X	None	Coated LA 12 lbs., WS	4/29, 5/8	LS only	3	8,476	2,825	4,283	34	65.1	45.9	11.4	13.8
24	None	LA 6 lbs., *Igepon* ½ lb., WS	4/29, 5/2	Same as Pre-blossom	2	15,397	7,698	7,031	0	10.5	10.5	82.6	87.2
26	None	LA 6 lbs., *Grasselli SS3* 1 lb., WS	4/29, 5/2	Same as Pre-blossom	4	21,267	5,316	4,649	0	18.8	18.8	68.9	77.2‡
23A	None	LA 6 lbs., *Summer Scalecide* ½ gal., WS	4/29	Same as Pre-blossom	1	5,637	5,731	4,204	0	16.7	16.7	72.4	79.8
23B	None	LA 6 lbs., *Summer Scalecide* ½ gal., WS	4/29, 5/6	Same as Pre-blossom	4	23,016				12.7	12.7	79	84.6
23X	None	LA 6 lbs., *Summer Scalecide* ½ gal., WS	4/29, 5/6	LS only	1	5,920	5,920	5,304	0	40.5	40.5	33	50.9
27A	None	LA 6 lbs., *Sunoco Spray* ½ gal., WS	4/29	Same as Pre-blossom	2	10,598	5,499	4,754	0	38.1	38.1	37	53.8
27B	None	LA 6 lbs., *Sunoco Spray* ½ gal., WS	4/29, 5/7	Same as Pre-blossom	1	4,014	4,014	3,629	0	16.3	16.3	73	80.3
27X	None	LA 6 lbs., *Sunoco Spray* ½ gal., WS	4/29, 5/7	LS only	1	2,275	2,275	2,385	4.8	49.1	46.8	18.8	37.5
29	None	Cuprous cyanide 2 lbs.	5/1	Same as Pre-blossom	1	2,473	2,473	3,171	22	44	34.3	40.1	37.7‡
31	None	*Black Leaf 155B* 6 lbs., WS	5/1, 5/7	Same as Pre-blossom	4	9,262	2,315	5,173	55.2	57	25.3	5.8	2.5
28W†	None	LS only	5/2	LS only	5	8,602	1,720	4,230	59.3	60.5	23.3	0	0
28E	None	LS only	5/2	LS only	8	10,139	1,267	3,707	65.8	73.5	24.6	0	0

* For a description of all of the substances see text under materials tested. LS = liquid lime sulfur, LA = lead arsenate, LP = lignin pitch, WS = wettable sulfur, Min. oil = mineral oil, CAS = copper ammonium silicate, and NS = nicotine sulfate.

† Serves as a check to plats No. 6, 7, 8A, 8B, 8X, 23A, 23B, 23X, 24, 26, 27A, 27B, 27X, 30 and 31. Plat No. 28E is the check for all other plats not mentioned.

‡ Definite injury caused by the treatment. In the case of plat 30 this took the form of foliage "burning," with plats 26 and 29 it was a russetting of the fruit.

1934 season's results appeared in the JOURNAL 28(2):376–9. The present deals with work done on the project in 1935.

These insecticide tests have been conducted both seasons in one of the orchards of Fishkill Farms,[2] Fishkill, N. Y. This 45-acre block is 21 years old and McIntosh is the principal variety. A group of trees six rows wide and 44 rows long lying near the center of the orchard comprised the experimental block in 1935. This was divided into 72 plats and subplats; the number of trees per plat varied from one (subplats principally) to 18. Thirteen trees sprayed with lime sulfur and distributed at random through the block served as controls. From the data taken at harvest it was evident that the infestation was remarkably uniform. This was not an accidental occurrence, however, as the block was selected originally on the basis of numerous sample examinations of the trees for their egg-mass populations. The egg masses become bleached out to a light gray color near the close of the dormant period in the spring and are then readily visible to the unaided eye. Since the infestation appeared to be somewhat lighter in the extreme western quarter of the block it was deemed fairer to base efficiency calculations for plats in this area on the five control trees located there (plat 28W of table 1). The eight remaining controls were used as the basis for calculations with all other plats.

A record was taken of all picked and windfall fruit from all trees in the experimental block, totaling 710,777 fruits or approximately 4500 bushels. All apples showing evidence of having been fed upon by the leaf roller, regardless of the size of that injury, were considered injured fruit. The data given in table 1 are based on the record obtained from some of the McIntosh trees only. While data are not given on the 28 Baldwin and two Wealthy trees which were present in various plats, it may be of interest to mention that results closely approximated those for McIntosh, but on an average gave slightly higher control efficiencies.

The spray was applied with a single-nozzle spray gun under 400 pounds pressure at the approximate rate of 12 gallons per minute. The operator was stationed on the ground. An average of 11.6 gallons of spray per tree was applied for the dormant treatments, while 13.6 gallons was the dosage with larvicide sprays. As to size of the trees, there are these statistics for the McIntosh variety: average height 21.1 feet, average spread 23.4 feet, average trunk circumference 30 inches, average volume 5046 cubic feet, and average crop of the 69 trees which presumably bore a normal crop, 4395 fruits.

Materials tested.—The materials that have been used in the experiment described in this paper include the insecticides lead arsenate, cuprous cyanide, nicotine sulfate, and a lubricating oil emulsion; the fungicides lime sulfur, an elemental wettable sulfur, cuprous cyanide, and copper ammonium silicate; and various adhesives, wetting and spreading agents. A fungicide has been included in all sprays applied after the trees were in foliage for protection against the fungous disease apple scab. A description of materials and their origin follows: in some cases the rate at which the product was used is given, otherwise this information will be found in table 1.

[2] To the owner, the Honorable Henry Morgenthau Jr., and his orchard foreman Mr. James Bailey, the writers take this opportunity to extend their thanks for generous cooperation.

BLACK LEAF 155 B.—A proprietary fixed-nicotine product consisting of 1 pint nicotine sulfate in each 6 pounds of bentonite clay and the ingredients to form zinc oleate when added to water. Tobacco By-Products and Chemical Corp., Louisville, Ky.

COATED LEAD ARSENATE.—Acid lead arsenate and lead oleate. This product occurs in paste form containing about 50 per cent water. Mechling Bros. Chemical Co., Camden, N. J.

COPPER AMMONIUM SILICATE.—A fungicide containing approximately 15 per cent metallic copper. Used at a rate of 2 pounds with hydrated lime 4 pounds in 100 gallons spray. Trade name *Coposil*. California Spray Chemical Co., Elizabeth, N. J.

CUPROUS CYANIDE.—The product used contained 86.08 per cent cuprous cyanide and 13.9 per cent wetting and spreading agents. Trade name *Kutane*. E. I. du Pont de Nemours & Co., Niagara Falls, N. Y.

FISH OIL.—Described by the dealer as being "a light-pressed Menhaden fish oil." Werner G. Smith Co., Cleveland, Ohio.

GRASSELLI SS3.—Consists of a synthetic resinous compound combined with sodium oleyl sulfate. A sticking, wetting and spreading agent. Grasselli Chemical Co., Cleveland, Ohio.

IGEPON.—A condensation product of oleic acid and oxyethane sodium sulfonate. A wetting and spreading agent. General Dyestuff Corp., New York City.

LEAD ARSENATE.—Powdered form of acid lead arsenate.

LIGNIN PITCH.—A wetting and spreading agent. Trade name of product used, *Goulac*. American Gum Products Co., New York City.

LIQUID LIME SULFUR.—Tested 33° Beaumé. Used at the rate of 1 gallon to 50 gallons water.

MINERAL OIL FOR DORMANT SPRAYS.—A lubricating oil of about 100 seconds viscosity and containing approximately 65 per cent unsulfonatable residues. An emulsion of this material was prepared in the spray tank with lignin pitch 1 pound to each 100 gallons spray. Trade name of oil, *Diamond Paraffin*. Standard Oil Co. of New York.

MINERAL OIL FOR FOLIAGE SPRAYS.—A white oil of 65–70 seconds viscosity and containing between 92 and 95 per cent unsulfonatable residues. Product used was a neutral emulsion containing 83 per cent oil. Dilutions of the emulsion were made on the actual oil content basis. Trade name of the emulsion, *Orthol K*. California Spray Chemical Co., Elizabeth, N. J.

NICOTINE SULFATE.—Containing 40 per cent nicotine sulfate. Brand name *Black Leaf 40*. Tobacco By-Products and Chemical Corp., Louisville, Ky.

PINE–TAR SOAP.—A soap with 13 per cent water and 3 per cent unsulfonated matter. Brand name *Grandpa's Wonder Pine–Tar Spray Soap*. Beaver-Remmers-Graham Co., Cincinnati, Ohio.

ROSIN FISH–OIL SOAP.—A flowable product containing 29 per cent soap. James Good Co., Philadelphia.

SUMMER SCALECIDE.—A proprietary miscible oil. B. G. Pratt Co., New York City.

SUNOCO SPRAY.—Described as a "petroleum soap" with 97 per cent active ingredients. Sun Oil Co., Philadelphia.

WETTABLE SULFUR.—A fungicide composed of approximately 98 per cent 325-mesh elemental sulfur with 2 per cent wetting and other agents. Used at the rate of 6 pounds in 100 gallons water. Brand name, *Magnetic Sulfur*. National Sulfur Co., New York City.

The results obtained with some combinations of the foregoing materials in the control of the fruit tree leaf roller are given in table 1.

Seasonal conditions.—The weather which prevailed during and immediately after hatching of the leaf roller eggs, or the operative period for the larvicidal treatments, presented distinctly opposing conditions the two seasons. In 1934 hatching was completed within five days as a result of unseasonably high temperatures. There was time only for the application of a single pre-blossom (pink) application, but this was made just at the beginning of hatching and no rain fell until six days later (1.11 inches) when hatching was completed. Presumably, the short-

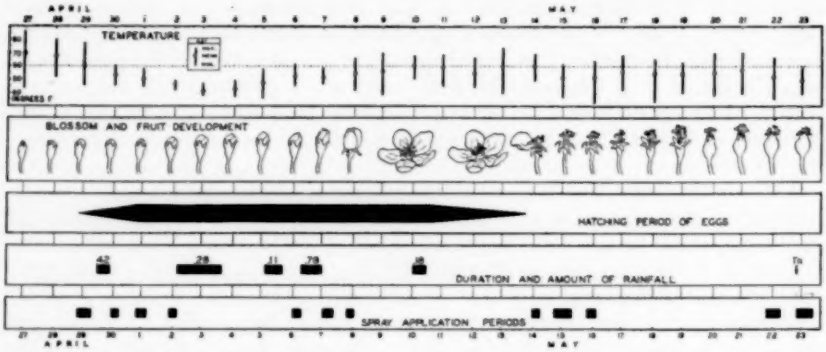

Fig. 1.—A diagrammatic presentation of records relating to the conditions under which the larvicidal treatments were applied in 1935.

ness of the hatching period and the absence of any serious new-growth or weather complications in 1934 should have constituted nearly ideal conditions for the action of properly timed sprays.

Conditions were probably as unfavorable in 1935 as they were favorable in 1934. Cool weather extended hatching over 16 days, while frequent precipitation and the constant appearance of new growth contributed to make it difficult to maintain adequate spray coverage. The interrelationship of hatching, host development, rainfall and periods when spray was applied in 1935 is shown in fig. 1. Hatching occurred at nearly the same time both seasons as regards host development: insect and plant development were simply accelerated in 1934 and delayed in 1935 over the normal condition.

Factors affecting efficiency computations.—Ordinarily it is possible to calculate the efficiency of treatment simply as the difference in per cent between the number of injured or infested units on the treated as against the control. In the opinion of the writers such a procedure may give erroneous values when applied to leaf roller-insecticide data.

Reasons for this lie in the nature of the injury inflicted by the pest and its distribution on a given tree. There are two classes of leaf roller fruit injury, injured fruits which survive attack and those which do not. Losses of the latter kind may cause a reduction in the yield ranging between zero and essentially 100 per cent, depending on the intensity of infestation. In the present instance the crop was reduced on the average more than 60 per cent on control trees. It is obviously desirable to include in efficiency computations this loss in fruits "fatally" injured as well as those bearing healed injuries among the harvested crop.

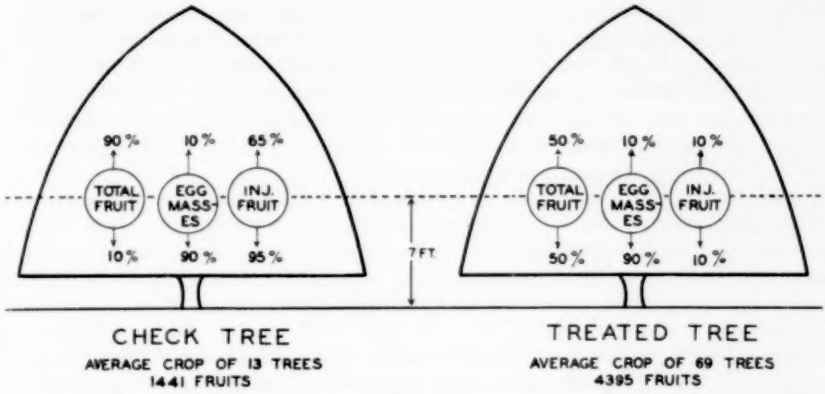

Fig. 2.—Approximate distribution of leaf roller egg masses, crop, and percentage of harvested fruit injured in two zones of the smaller treated and control trees in the 1935 experimental area. Reconstructed principally from data obtained from two 19-foot McIntosh trees. Owing to an unexpected heavy drop of the fruit prior to harvest it was necessary in the case of the treated tree to use data obtained in 1934 to show the proportion of fruit above and below seven feet and the rate of injury. Fortunately a record was taken on the control trees before the drop took place; hence all data for the check tree were obtained in 1935.

Another possible source of error in determinations of efficiency on the status of harvested fruit alone may arise from the unequal intensity of infestation on the tree. This would give a disproportionate weight in the percentage to the zone of lighter infestation. If the conditions existing in the Fishkill Farms orchard in 1934 and 1935 are typical of heavily infested plantings, then most of the crop surviving attack would occur in the upper half of the tree. Studies made by the writers show that this is a result of a concentration of the insect population in the lower part of the tree. Of the 813 egg masses counted on a 19-foot McIntosh tree, 91.1 per cent were on limbs within reach of the ground, or the lower 7 feet (including trunk) of the tree. On a 24-foot McIntosh tree 83.8 per cent of the 1213 egg masses were within 7 feet of the ground. (Incidentally, these studies indicate that the population in the 1935 experimental block was approximately 65,000 larvae per tree, on the assumption that 1000 egg masses containing 75[3] eggs each were present and allowing 10 per cent

[3] This was the average number of eggs found in 45 masses collected in this orchard in 1934.

loss through infertility and parasitism of the eggs.) Apparently most of the dispersion of caterpillars is downward or horizontal, as there is a close correlation between the intensity of injury and number of egg masses found in the several strata. With infestations as heavy as the present, therefore, the proportion of fruits fatally injured in the lower half of the tree is so much higher than in the top that few fruits attain maturity in the former zone. Consequently the percentage of harvested fruits injured is dominated by conditions existing in the tops of the trees. The several elements of this concept are illustrated in fig. 2.

As the number of fruits which survive attack can be determined definitely by an individual examination of the harvested fruits, there remains the problem of determining how many were fatally injured. In the present case this loss is expressed as the difference between the actual and theoretical yield. Trees sprayed during the dormant period with 6 and 8 per cent oil showed reduced yields as a result of the treatment. This loss has not been distinguished from the fruit fatally injured by the leaf roller in efficiency computations.

The theoretical yield has been calculated from data obtained on 69 of the McIntosh trees which were assumed to have a normal crop. These are the residue after eliminating all trees receiving dormant treatment and all trees showing a percentage of injured harvested fruit in excess of 25 per cent. No reduction in yield apparently took place until this percentage exceeded about 35 per cent, but for the sake of greater dependability, 25 per cent was set as the upper limit. All efficiency computations involving trees showing 25 per cent or less of the harvested fruit infested are based on the actual yield, regardless of whether this was short of or more than the estimated (theoretical) yield. The only important variable among the trees which would affect yield was some difference in size. Surely the amount of bloom and presumably the rate of fruit setting was uniform in all of the McIntosh trees in 1935.

Correlation studies were made on the 69-tree sample to determine what was a fairly accurate size measurement to use as a basis for estimating the crop of "unknown" trees. The correlation between yield and trunk circumference gave an r value of .751. The r value of the correlation between the calculated volume[4] of the tree and yield was .66. Since trunk circumference gave the better index to yield (size) this measurement was selected as the basis for yield calculations according to the following regression equation:

$$Y = 261.708X - 3437.36$$

where Y is the theoretical yield and X the trunk circumference. The values used to obtain the constants in the above equation are:

$r = .751$
Total fruit, mean = 4394.95, $\sigma = 1750.27$
Trunk circumference in inches, mean = 29.93, $\sigma = 5.02$

In table 1, where plats are represented by two or more trees, the percentage of injury for the plat is an average of the individual percentages

[4] Formula used: $\frac{2}{3}\pi a^2 b$, the tree assumed to be one-half of an ellipsoid, where a is the average radial spread of the tree and b is the height from the lowest limb.

for the several trees. There were only minor variations in the injury-rate of trees in the same plat so that other methods of arriving at this figure for the plat should give essentially the same result as the method used.

Expression of results.—The efficiency of the several treatments is expressed in two ways in table 1. In next to the last column it is calculated in the usual manner, according to the following formula:

$$\frac{Ak-Al}{Ak}\,100 = \text{percentage control efficiency (No. 2 of table 1)}$$

where Ak is the percentage harvest-injured fruit of the control plat based on the *actual* yield and Al the same for the treated plat.

The method of calculating efficiencies preferred by the writers and used in determining the values in the last column of table 1 may be expressed by the following formula:

$$\frac{(Tk+m)-(Tl+n)}{Tk+m}\,100 = \text{percentage control efficiency (Nos. 1 and 3 of table 1)}$$

where *Tk* is the percentage of harvest-injured fruit of the control plat based on the *theoretical* yield and *Tl* is the same for the treated plat, and *m* represents the estimated reduction in yield for the control plan and *n* for the treated.

Discussion and conclusions.—From the experimental evidence given in this paper and in the 1934 report, the writers draw the following conclusions:

Nearly equal control efficiencies were obtained with a dormant-applied 6 per cent oil spray functioning as an ovicide and the better lead arsenate or larvicidal treatments, if the damage attributable to the oil is disregarded. With the same qualification, maximum efficiencies have been shown to result where both oil and arsenical were used.

The dormant sprays applied in these tests caused a reduction in yield as a result of killing or weakening of the buds. This loss was pronounced where the 8 per cent oil emulsion was used. In most situations an emulsion containing 6 per cent of the type of oil used in these tests would probably not cause a sufficient reduction in the crop to be objectionable commercially and very little would be lost in insecticidal action over an 8 per cent strength. Small crop reductions may be justifiable in the light of overwhelming benefits in insect control especially if no satisfactory alternative treatment is available. However, the injury hazard must be recognized as a weakness. When the treatment causes a reduction in yield it appears logical to include this loss with that caused by the insect in computing the efficiency: this has been done in the present instance. Lime sulfur was the only ingredient of the larvicide sprays which definitely has been known to affect the yield under some conditions. In these experiments, trees in plats receiving lime sulfur gave a slightly higher yield than those sprayed with elemental sulfur. But even if the possibility of a loss is admitted, it would be a more or less constant loss as the control trees and plats receiving oil as the only insecticidal treat-

ment were sprayed with lime sulfur at the times larvicidal sprays were applied.

Lead arsenate sprays applied directly after and 7 days after blossoming contributed much more to whatever control was obtained than preblossom sprays in 1935. In one instance (plat 14D) the control obtained with the two post-bloom sprays was essentially the same as when a schedule of two pre and two post-bloom sprays (plat 14A) was applied. In relation to the development of the insect, these findings suggest that the spray coverage maintained directly after the hatching of the eggs was much more important in protecting the fruit in 1935 than that present immediately before and during hatching. Whether or not this situation always holds can only be determined by future investigation under varying conditions. The tests of 1934 were not planned in such a way as to throw light on this point. It is suspected that both pre and post-blossom spraying are important under average conditions.

Lead arsenate used at the rate of 6 pounds per 100 gallons of water gave significantly higher efficiencies than the 3:100 rate in four of five comparisons. Differences in favor of the 6:100 rate ranged from 40.4 per cent (plats 20A and 18) when combined with fish oil and wettable sulfur to no apparent difference in combination with one-half per cent mineral oil and wettable sulfur (plats 16 and 14A).

Lime sulfur–lead arsenate combinations were poorer by as much as 15 per cent (plats 8B and 11A) compared with mixtures of wettable sulfur and lead arsenate.

The presence of adhesives or wetting and spreading agents exerted a considerable influence on lead arsenate and wettable sulfur combinations. Where other conditions were constant, the efficiency was found to range between 85.2 per cent when one-half per cent mineral oil was present down to 26.6 per cent when this was replaced with 1 per cent rosin fish-oil soap (plats 14A and 30). A knowledge of the physical properties imparted to the spray mixture through the addition of these substances would no doubt provide explanations for most of these differences. Studies designed to obtain this information are in progress and it is planned to develop this phase of the subject in a later paper. None of these substances apparently possess any appreciable insecticidal value at the dilutions used against leaf roller. The most likely suspect, one-half per cent mineral oil, gave a negative value when tested alone in 1935.

Results obtained with nicotine preparations were not as promising in 1935 as in 1934. Seasonal differences may be the explanation.

In spite of weather conditions which presumably hindered (in 1935) or favored (in 1934) the utilization of lead arsenate for the control of the leaf roller, it was possible to obtain essentially the same results both years with comparable mixtures.

Russetting of the fruit was observed where cuprous cyanide and where lead arsenate and *Grasselli SS3* were used, while foliage injury was prominent on the plat receiving lead arsenate and rosin fish-oil soap. No fruit or foliage injury apparently took place from the combinations of mineral oil with the fungicides copper ammonium silicate and the wettable sulfur.

PARTIAL SECOND BROOD OF PLUM CURCULIO IN VIRGINIA

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Riley suspected that the plum curculio, *Conatrachelus nenuphar*, was occasionally two brooded, or that a small per cent of the first-generation beetles would lay eggs before going into hibernation. After a study of the insect in 10 states covering the period from 1902 to 1910 inclusive, Quaintance & Jenne (*5*) stated that "little information on the tendency of the insect to produce a second brood under field conditions has been secured." They mention, however, a partial second brood at Washington, D. C., in 1905 and at Barnesville, Ga., in 1910. After two years' study of the insect at Fort Valley, Ga., Snapp (*7*) stated that two generations occurred annually in central Georgia and that in 1922 a partial third brood was observed. Leiby & Gill (*3*) established a laboratory at Aberdeen, N. C., and observed that 20 per cent of the females that emerged in 1922 deposited eggs before hibernating. In the following year Leiby & Harris (*4*) reported that only 10 per cent of the first-brood females deposited eggs. The investigations reported above indicate that in the southern peach belt reaching from North Carolina to Georgia a second brood of economic importance occurs every year.

During the period mentioned above only a few observations have been reported from the northern half of the peach belt. Sanders (*6*) studied the insect at Berlin, Md., in 1923, and found only one brood. He concluded from field observations that there was no destructive second brood during the four years that followed. Chandler (*1*) observing the insect at Carbondale, Ill., reported a small second brood in 1927. The situation in Delaware (*2*) was somewhat singular in that there was a partial second brood in the vicinity of Bridgeville in 1929, whereas in the other peach sections of the state no second brood occurred. Prior to 1929 no serious state-wide losses were reported by Virginia peach growers and no systematic records were made; but following the outbreak in that year, field studies were made in Albemarle, Augusta, Roanoke, and Rockingham counties. The life history was studied at Staunton.

The conditions are very favorable to the curculio in the peach section in Albemarle and Roanoke counties. In both sections there are many peach and apple orchards which furnish food in summer and there are large areas in timber in which the beetles may hibernate. In Augusta and Rockingham counties the season is later, and conditions apparently are not so favorable. The abundance of the beetles varies, but Mr. Woodside reports that in some seasons the adult insects have been present in very small numbers in Augusta and Rockingham counties, and that the numbers captured by jarring did not give an adequate picture of the emergence from hibernation.

In the years 1930 to 1934 inclusive the insect showed only a slight tendency to develop a second brood in the Crozet section. For the most part, the insects used in the life-history work were collected in the vicinity of Crozet and the studies were made at Staunton. Woodside (*8*)

states that 327 first-brood adults were under observation in 1930 and only one egg was deposited. In 1931, 1932 and 1933 there was no oviposition by first-brood females. In 1934 about 200 beetles of the summer brood were confined in two battery jars and were supplied with apples. This fruit was removed to baskets every few days, and from it emerged 22 larvae between July 25 and September 21. Two of these pupated, but neither survived to transform. With these exceptions, there was no second brood in the insectary during the five seasons of these studies.

In July 1935, large numbers of adults were found in peach orchards in

Table 1.—Plum Curculio in Virginia, 1930–35.

	1930	1931	1932	1933	1934	1935
			First Brood			
Eggs deposited	May 2—July 6	May 10—June 25	May 28—June 20	May 8—June 29	May 19—June 20	May 10—June 20
Length of egg stage and feeding period combined	22.4 days	18.8 days	21.6 days	23 days	19.7 days	20.9 days
Time of leaving fruit by larvae in insectary	June 2—July 29	June 23—July 8	June 27—July 15	June 4—July 18	June 14—July 24	June 2—July 4
Time of leaving fruit from drops	May 22—June 15		June 3—July 9			May 29—June 20
Length of time spent in ground by larvae, pupae and adults	31.4 days	29.8 days	32 days	31.8 days	29.2 days	34.5 days
Time of emergence	June 20—Sept. 2	July 8—July 12	July 8—Aug. 10	July 3—Aug. 3	June 28—Aug. 16	July 1—July 25
Time of emergence of adult from larvae from drop fruit	June 30—Aug. 9					June 30—Aug. 1
			Second Brood			
Eggs deposited						July 5—Aug. 22
Time spent in fruit						21.2 days
Left fruit						July 23—Aug. 25
Time spent in ground						26 days
Emerged						Aug. 18—Sept. 17

both the Crozet and the Roanoke sections. The actual number of beetles present varied in different orchards. As many as 10 beetles per tree were found, and in one instance 40 beetles were taken from a tree at one time. Close examination of the scales on these adults showed that most of them had just emerged from the soil. Adults of the overwintering brood were readily separated because of the worn condition of the scales. Dissection of the females showed that half of them contained fully matured eggs; and a second brood was soon revealed by presence of larvae in the peaches and also by the deposition of eggs by adults placed in cages.

The insectary and field studies were carried on again in 1935 as in previous years, the collections being made largely at Crozet and the rearing work being done at Staunton. Of 14 first-brood females captured by jarring, six deposited eggs totaling 304; and of 10 reared in the insectary, three females deposited eggs totaling 128.

It is believed that in the Crozet and Roanoke sections about 50 per

cent of the first-brood females deposited eggs in 1935. No life-history records were made in 1929, but it is now apparent that the worms in the peaches in August of that year were second-brood worms; and, judging by the injury, there was probably almost a complete second brood. Table 1. gives the summary of the life-history records made by Woodside for the years 1930 to 1935 inclusive. Study of these records seems to indicate that the life history in the early part of the season in 1935 was very similar to that in the other years. The summer of 1929 and 1935 were referred to as wet seasons, whereas the other years were mostly dry.

It is concluded from a study of the history of the insect and the other data that Virginia is on the border line between the one-brooded and the two-brooded areas and that in seasons that are favorable to the curculio, a partial second brood occurs.

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NOTES AND OBSERVATIONS ON THE PISTOL CASE-BEARER

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The pistol case-bearer, *Coleophora malivorella* Riley, is not generally recognized as being a serious major pest of the apple industry. It has been present in the Shenandoah-Cumberland fruit belt for many years but only within recent years has it become a pest of major importance. The first record of its importance in West Virginia was an outbreak in a large commercial orchard near Ranson in 1927. Since 1927 there have been outbreaks in a number of orchards throughout the Shanandoah-Cumberland fruit belt. These outbreaks have not been concentrated in local areas but have been generally distributed throughout the entire region. In many of these orchards such dense populations have occurred that is has been necessary to apply special sprays in order to prevent serious damage to the orchard.

The reason for the building up of such dense populations of this pest in widely scattered orchards is not definitely known. All known out-

breaks have occurred in commercial orchards; none having been recorded for abandoned orchards. Since it occurs in practically all orchards but normally only in limited numbers, and especially so in abandoned orchards where only natural control measures exist, the conclusion is that this insect is normally kept under control by parasites and other natural enemies. If a heavy population develops it may do severe damage before it can be brought under control. Parasites and other natural enemies will eventually build up to the point where, unaided, they will reduce heavy infestations of the case bearers to the point where they will no longer be injurious to the orchard but this may require several years. In 1930 a large commercial orchard adjoining the Kearneysville station was very heavily infested but since that time the population has been reduced, without the application of special sprays, to the point where it is no longer serious.

The pistol case-bearer serves as an ideal host for a large number of parasites. Thirty-six species of parasites have been reared from it. Thirty-three of these were larvae and three were egg parasites.[1] Of this large number only five are normally common enough to be a significant factor in control. The five most abundant species are: *Microbracon pygmaeus* Prov., *Eurydinota lividicorpus* Girault, *Habrocytus* sp. nov., *Hemiteles tenellus* Say, and *Meteorus vulgaris* Cress. Most of the other species were present only in limited numbers. Normally these parasites keep this pest well under control but where the parasite population is very light the case bearer may build up its numbers in spite of the standard spray treatments. Thorough spraying with arsenate of lead will normally effect control but when dense populations occur this control will not be rapid enough to prevent severe losses.

It is very desirable to have some effective spray material which can be applied with immediate and satisfactory results to prevent severe damage. Due to the feeding habits of this insect a spray which can be applied during the dormant season would be most satisfactory because at that time a more thorough coverage can be obtained. It is practically impossible to obtain complete coverage of this insect during the growing season due to the foliage and also to the fact that more than 92 per cent of the larvae feed on the under surface of the leaves.

None of the large number of materials and combinations tested as dormant sprays has given satisfactory results. Some of the coal-tar distillates, petroleum oils and wood creosotes have given a fair degree of control, but it has been necessary to use them at such high concentrations, and the control obtained was such, that their use cannot be recommended commercially. It many cases the heavy concentrations of these spray materials have been injurious to the trees. Their cost also prohibits their use commercially.

The nicotine–oil combination is the most effective larvicide tested for the control of the case-bearer. To be effective a very thorough and timely application is necessary. Summer oil used at the rate of one gal-

[1] The parasites were identified by Mr. A. B. Gahan of the United States National Museum, Washington, D. C., or through the kindness of Mr. Gahan by Mr. R. A. Cushman of the Museum; and by Mr. C. F. W. Muesebeck.

lon per 100 with nicotine sulfate 1:800 is just as effective as, and also cheaper than the recommended nicotine–penetrol combination. The use of solids such as arsenate of lead, Bordeaux mixture and lime with this combination reduces its efficiency. A very thorough application is necessary for complete coverage of the insects which feed mainly on the under surface of the leaves. This spray, to be most effective, should be applied as soon as possible after the eggs have hatched. Once the cases are well formed and have hardened, the larvae are much more difficult to kill. With the best of spraying it is very difficult to get above 85 per cent control, which is not very satisfactory where dense populations occur.

Recent work has shown that a one per cent summer oil applied as an ovicide is very effective in controlling the casebearer. For best results, it is necessary that this spray be applied when the maximum number of eggs are present on the leaves. Since more than 92 per cent of the eggs are laid on the upper surface of the leaves it is less difficult to obtain thorough coverage with an ovicide than with a larvicide spray, which must be applied at a time when the majority of the larvae are on the under surface of the leaves. This spray also has the advantage of being much cheaper than the recommended nicotine–oil larvicide spray. The use of such solids as arsenate of lead, Bordeaux mixture and lime also reduces the ovicidal efficiency of this material. During the past two years this summer oil spray has been applied commercially, in a number of large orchards in West Virginia, with very satisfactory results. If thoroughly applied at the proper time, one application will reduce a dense population of the pistol case-bearer to the point where it will not cause serious damage to the orchard the following season.

SOME TESTS OF PYRETHRUM, DERRIS AND NICOTINE MIXTURES AGAINST CABBAGE WORMS

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During the course of field experiments on Long Island with non-arsenical insecticides for the control of cabbage worms, it has become increasingly apparent that not all species of worms infesting crucifers were affected to a similar degree by mixtures containing the powdered roots of derris, cubé or timbo. In general it has been observed that such insecticides have given satisfactory control of the imported cabbage worm[1] but were not so effective against the cabbage looper,[2] much less for anything pertaining to the destruction of the zebra caterpillar.[3] In the case of the cabbage looper it may be said that the difficulty seemed to lie chiefly in the extent to which older worms escaped poisoning whilst with the zebra caterpillar all instars seemed to be highly immune to their effects.

With a view to obtaining more specific information concerning the re-

[1] *Pieris rapae* L.
[2] *Autographa brassicae* Riley.
[3] *Mamestra picta* Harris.

Table 1.—Data relative to the effectiveness of derris powder applied as a suspension in water, as a stomach poison for cabbage worms.

Spray Formulae	Numbers for *A. brassicae* or *P. rapae*		*Autographa brassicae* First—Third Instars *Percentage Dead Worms After 96 Hrs.*		*Pieris rapae* Second—Fourth Instars *Percentage Dead Worms After 96 Hrs.*		*Mamestra picta* Second—Third Instars		
	Worms	Tests	Series 1	Series 2	Series 1	Series 2	*Total Numbers* Worms	Tests	*Percentage Dead Worms After 96 Hrs.*
Derris powder* 2½ g. Skim milk powder 2½g. Water 500 cc.	240	12	72.5±1.89 (45:1)†	70.5±1.57 (40:1)	90.8±1.35 (9:1)	82.5±3.78 (29:1)	132	8	10.2±.36 (19:1)
Derris powder 2g. Skim milk powder 2½ g. Water 500 cc.	240	12	61.7±2.41 (19:1)	62.7±1.76 (22:1)	87.5±1.45 (158:1)	74.2±2.68 (29:1)	140	8	8.7±.64 (16:1)
Derris powder 1¼ g. Skim milk powder 2½ g. Water 500 cc.	240	12	56.7±1.88	57.1±1.49	81.7±1.12	65 ±1.75	135	8	7.8±.39
Checks	80	4	0	5	10	10	142	8	3.6
			Range of Temperature and Relative Humidity During Experiment						
Temperature Max.			87°F	82°F	88°F	90°F	86°F		
Min.			70	60	64	69	66		
Mean			76	73	76	75	77		
Relative Humidity Max.			100%	98%	100%	100%	100%		
Min.			60	40	44	62	45		
Mean			92	81	86	90	84		

* Ground derris root of 4½ per cent rotenone content and 16 to 18 per cent total extractives, as supplied by the firm of W. Benkert & Co., New York City.
† Odds as to difference between higher and lower strengths in treatment being significant.

action of these three species of cabbage worms to derris and other non-arsenical insecticides that might be of value commercially, the following tests were carried out under insectary conditions during the past two seasons. The plan of procedure in general may be briefly described as follows: As opportunity occurred worms were gathered in the field in large pans or glazed crocks and kept in the shade. Such larvae were treated on the day collected or that following. Larvae were divided into equal numbers and in proportions according to size. They were finally placed into aluminum dishes, which were lined with absorbent paper and bordered with a heavy dressing of tanglefoot. A small water container was placed in each dish to preserve the foliage. Each test was usually replicated six times during each series. Twenty worms were usually used as the unit per test. Sprays were applied by an electric-type sprayer onto seedling leaves of uniform size, two being placed in each dish. The spray on such leaves was allowed to dry before being exposed to larval feeding. Dust mixtures were applied by means of small home-made dusters. Each consisted essentially of a 4½-inch length of large-bore, stout glass tubing, plugged at each end with a perforated rubber cork. Through each cork was passed a short length of small-bore glass tubing one end of which was bent slightly and placed inside the large-bore tube. A rubber bulb was attached to the other end of one of the tubings. Such outfits had the advantage of being quickly cleaned, assembled and weighed on scales to check the rates of application. In the case of poisons applied to the foliage for purposes of ingestion larvae were allowed to feed for 48 hours, after which they were fed on untreated foliage for another 48 hours. In the case of dusts applied for purposes of direct contact with the insect, each quota of worms was placed on a sheet of paper on the ground and dusted as evenly as possible, after which the worms were removed to their respective "cages" for further observation.

Derris powder as a stomach poison.—In tests of water suspensions of derris root as a stomach poison a stock powder was used analyzing approximately 4½ per cent rotenone and 16 to 18 per cent total extractives. Suspensions were prepared containing 2½, 2 and 1¼ grams respectively of such root in 500 cc. of water, to which was added powdered skim milk as a spreader and sticker. This mixture was applied at an average rate of 5 to 6 cc. per leaf.

In the case of the imported cabbage worm it was evident that for some unexplainable reason the larvae were soon sensibly affected by the close proximity of derris residue on the foliage. Within two hours after treatment had commenced many of the larvae were in distress. In comparison, feeding in the untreated "cages" had proceeded vigorously and quietly.

In the case of the cabbage looper it was evident that the larvae did not exhibit the same degree of susceptibility to the influence of derris root as did the imported cabbage worm. The larvae were not so obviously distraught by the presence of treated foliage and continued to feed sparingly. Most of the subsequent mortality occurred to worms in the earlier stages of development.

In the case of the zebra caterpillar there was little, if any, significant difference observable in the behavior of larvae on treated and untreated

foliage. At all dilutions the suspension had apparently little effect as a stomach poison.

Data pertaining to these series of tests are summarized in table 1.

It will be seen here that the greatest mortality to *A. brassicae* and *P. rapae* occurred where derris was used at greatest strength, a dosage equivalent to 4 pounds of such powdered root to 100 gallons of water. Despite the fact that the samples of larvae of *rapae* contained worms of greater average development, there was a relatively higher average kill with *rapae* than with *brassicae* at any given treatment.

Table 2.—Data relative to the effectiveness of pyrethrum and pyrethrins-containing dust mixtures as contact insecticides for the larvae of the cabbage looper.

Dust Formulae	Total Number Worms	Tests	Percentage Dead Worms After 48 Hrs. Series 1	Series 2	Series 3	Average
Pyrethrum powder* 50 gm. Clay 50 gm.	380	18	87.5±1.49 (29:1)‡	72.1±1.88 (45:1)	71.7±3.34 (174:1)	77.1
Pyrethrum powder 30 gm. Clay 70 gm.	366	18	79±3.39 (666:1)	63.3±3.1 (15:1)	51.7±1.41 (124:1)	64.7
Pyrethrum powder 20 gm. Clay 80 gm.	375	18	58.4±2.98	59.2±2.95	40.8±1.6	52.8
Checks	124	6	7	5	5	5.7
Pyrethrin powder† 2 gm. Talc 50 gm.	240	12	91.7±1.12 (98:1)	95.7±.75 (50:1)		94.6
Pyrethrin powder 1 gm. Talc 50 gm.	240	12	81.7±1.42	85±2.31		83.3
Checks	80	4	7.5	7.5		7.5
Relative Proportion of Larvae of Different Sizes						
Pyrethrum powder treatments			large 10 medium 6 small 4	large 14 medium 6 small 3	large 15 medium 4 small 1	
Pyrethrum powder treatments			large 15 medium 4 small 1	large 16 medium 3 small 1		
Range of Temperature and Relative Humidity at Treatments, 11 a.m.—3 p.m.						
Pyrethrum powder treatments			74—65° F 50—65%	72—60° F 45—65%	69—64° F 44—58%	
Pyrethrin powder treatments			77—66° F 65—85%	65—60° F 42—30%		

* From R. J. Prentiss & Co., New York City, consisting of Japanese flowers of .9 per cent pyrethrin content.
† Product of McLaughlin, Gormley, King & Co., Minneapolis, containing an inert filler impregnated with an extract of pyrethrum to 5 per cent pyrethrin content.
‡ Odds as to difference between higher and lower strengths of treatment being significant.

Pyrethrum and pyrethrins as contact insecticides.—In the hope of obtaining an insecticide that might provide a greater degree of effectiveness than derris when used against the cabbage looper, especially during the later stages of larval development, tests were carried out with powdered pyrethrum flowers and a powder impregnated with an extract containing pyrethrins, applied as a contact insecticide in dust form. The formulae for such mixtures are given in table 2. The comparative strengths of these mixtures as expressed in pyrethrin content[4] may be said to be about as follows: for pyrethrum dusts .45, .27 and .18 per cent pyrethrins, for the impregnated dusts .2 and .1 per cent pyrethrins.

[4] By the term pyrethrin is meant the inclusion of pyrethrins I and II.

The rate of application for the pyrethrum–clay dusts averaged .75, .9 and 1.1. grams per test of 20 worms in series 1, 2 and 3 respectively; for pyrethrin powder–talc dusts, 1.1 grams in the two series.

As with derris suspensions, the effect of these dusts was more marked in the case of smaller larvae than with the larger. However, even with the larger larvae many were rendered inanimate for a more or less extended period. The chief difference in results from using the two types of pyrethrum dusts seemed to be that more of the older larvae were capable of revival from the powdered pyrethrum flowers than from the dusts in which extracts of pyrethrum flowers alone formed the active principle.

Table 3.—Data relative to the effectiveness of nicotine dusts as contact insecticides for the zebra caterpillar and cabbage looper.

Source of Nicotine and Nicotine Content in Hydrated Lime Dust		*Mamestra picta* First—Second Instars				*Autographa brassicae* Third—Fourth Instars			
		Total Numbers		*Percentage Dead Worms After 2½ Hours*		*Total Numbers*		*Percentage Dead Worms After 2½ Hours*	
	Per Cent	Worms	Tests	Series 1	Series 2	Worms	Tests	Series 1	Series 2
Nicotine sulfate 40%	4	480	12	90±1.38 (80:1)*	94.6±1.47 (454:1)	240	12	7.5	10.8
	3	360	14	80±1.53	82.1±1.92 (124:1)	240	12	4.2	9.2
	2	240	6		73.3±1.13	240	12	5.8	7.5
Free nicotine	4	480	12	84.9±1.58 (1999:1)	78.8±1.67 (174:1)				
	3	360	14	74.7±.87	62.9±1.6 (40:1)				
	2	240	6		53.8±2.49				
Checks		160	4	1.9	6.4	80	4	0	5
Relative Proportion of Larvae of Different Sizes Per Test				small 40		large 14 medium 5 small 1		large 15 medium 4 small 1	
Range of Temperature and Relative Humidity at Treatment				70–72° F 98%		70–74° F 60–46%		72–80° F 64–48%	

* Odds as to difference between higher and lower strengths of treatments being significant.

The data for these experiments are summarized in table 2. Here it will be seen that the indications are that with pyrethrum dusts greater concentrations of powdered pyrethrum flowers will be needed than were used to effect what is considered a satisfactory kill of the larger worms of *A. brassicae*, and this despite the fact that according to pyrethrin content the highest strength of ground pyrethrum flowers used was more than two to four times the strength of dusts having extracts of pyrethrum flowers as the active principle.

Nicotine as a contact insecticide.—During the autumn of 1934 the zebra caterpillar occurred in unusually large numbers on Long Island on cauliflower and cabbage, and owing to the ineffectiveness of derris preparations in controlling this pest it was deemed necessary to find, if possible, some means for checking the pest other than the time-honored method by crushing. Trials were made of nicotine and pyrethrum prepa-

rations, and both gave promising results when applied in heavy applications by the so-called spot-dusting method whilst the larvae were confined in colonies. Owing to the comparatively high cost of ground pyrethrum flowers in 1934 chief attention was given to the possibilities of nicotine dusts. These dusts are described in table 3. They were applied in the insectary at relatively heavy rates to the zebra caterpillar. In addition, tests were made in 1935 with nicotine dusts and the cabbage looper, the rates of application averaging 1.3 to 1.5 grams per test.

In comparison with derris treatments, nicotine dusts, as applied, were much more effective in killing the zebra caterpillar in the earlier instars. Dusts having 40 per cent nicotine sulfate, as the source of nicotine, were more effective than those having 50 per cent free nicotine, as its source. Evidently dusts of 3 or 4 per cent nicotine strength were necessary to produce a fairly high degree of mortality. On the other hand, the most effective dusts for the zebra caterpillar were, as applied, relatively ineffective against the cabbage looper, what mortality there was being restricted in most cases to larvae in the earlier instars.

The data relative to these experiments are summarized in table 3.

Summary.—Powdered derris root (4½ per cent rotenone, 16 to 18 per cent total extractives) at strengths comparable to 4, 3 and 2 pounds of powder per 100 gallons of water, gave a higher degree of mortality in the case of the imported cabbage worm than to larvae of the cabbage looper, and further, such mixtures were relatively ineffective to the zebra caterpillar. In the case of the cabbage looper the degree of effectiveness obtained at the highest derris strength was considered scarcely satisfactory.

In tests with pyrethrum and so-called pyrethrins-containing dust mixtures in contact applications for the larvae of the cabbage looper, at strengths of about .45, .27 and .18 per cent pyrethrin content for mixtures containing ground pyrethrum flowers, and of about .2 and .1 per cent content for mixtures containing an impregnation with extract of pyrethrum flowers, the latter type of dust was the more effective.

Nicotine sulfate–hydrated lime dusts of 3 and 4 per cent nicotine content gave satisfactory results in a heavy contact application for the earlier instars of the zebra caterpillar; in contrast a lighter application to older larvae of the cabbage looper was ineffective.

STICKERS FOR DERRIS APPLIED AS AN INSECTICIDAL SPRAY

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It has been found that foliage may be protected from severe injury by the Japanese beetle by spraying with a suspension of powdered derris root.[1,2] The use of this material is of advantage because no con-

[1] **Osburn, M. R.** 1934. Experiments with rotenone and derris to repel the Japanese beetle, *Popillia japonica* Newm. JOUR. ECON. ENT. 27(1):293. Feb.

[2] **Fleming, W. E.,** and F. E. Baker. Derris as an insecticide and repellent against the Japanese beetle. Publication pending.

spicuous residue is left on the plants, and the material is probably not injurious to man or animals, but because of its poor adhesion to the foliage it was necessary to repeat this spray after every rain. A laboratory investigation was therefore initiated in the fall of 1934 to develop a satisfactory sticker for derris.

Procedure.—The oils, waxes and resins that were tested as stickers were emulsified with ammonium caseinate or triethanolamine caseinate; the asphalt and the latex were obtained in emulsified form; agar-agar

Table 1.—Derris in combination with different stickers removed from glass plates by washing.

Sticker	Average Total Loss *Per Cent*	Average Loss of Derris *Per Cent**
Asphalt	2.7	
Coumaron resin	5.6	
Latex, crude	7.3	
Rosin residue, type II	7.5	
Rosin residue, type I	8.8	
Rosin residue, type III	10.1	
Agar-agar	11.8	
Sardine oil, blown	12.1	
Castor oil, blown	18.9	
Glue and formaldehyde	23.2	
Bentonite†	24.5	
Apple wax	32	37
Tanglefoot	35.3	36
Linseed oil, boiled	44	
Flour, cooked	45.8	
Halowax	51.6	
Blood albumen and formaldehyde	55	
Menhaden oil, raw	56	53
Casein	62	
Skimmed-milk powder	62.5	
Irish moss	66	
Paraffin	69.5	70
Flour, raw	76.7	
No sticker	88	91
Bone glue	100	

* Per cent of derris originally present.
† Equal weights of derris and bentonite were used.

and flour were dispersed in water in the usual manner. In the preliminary experiments the sprays contained 2 per cent of powdered derris and 1 per cent of the sticker. The more promising materials were then tested with various proportions of the stickers.

Preliminary Tests on Glass Plates.—In the preliminary tests each spray was applied to six clean tared glass plates, $3\frac{1}{4}$ by 4 inches, set in a horizontal position on a revolving table. Each spray mixture was placed in a small glass tank, which was equipped with a mechanical agitator, and applied with a commercial paint gun in a fixed position, 30 inches from the plates, under a pressure of 25 pounds per square inch. Each plate was passed through the spray three times, dried in air at 95° F (35° C) for three hours and weighed on an analytical balance to .1 mg. It was then washed by allowing 1 liter of water at 68° F (20° C) to run through perforations in the bottom of a can suspended three feet

above the plate, the time required being about 5 minutes. This amount of water is equivalent to 2.5 inches of rainfall. The washed plates were dried and reweighed to determine the loss in weight. The average percentage loss from the different plates is given in table 1.

To determine whether the loss in derris is proportional to the total loss, a few of the plates were analyzed by the colorimetric procedure of Gross & Smith.[3] These results, given in table 1, indicate that the loss in the weight of derris is proportional to that of derris and sticker.

Tests on Bean Foliage.—The materials that appeared to be the most promising on glass plates were then tested on bean foliage. In this procedure two groups of plants having the same total leaf area were sprayed at the same time. The amount of derris was determined by chemical analysis on one group of leaves without further treatment and

Table 2.—Derris removed from bean foliage by washing when present in combination with different stickers.

Sticker	Average Loss by Washing Foliage	
	String Bean *Per Cent*	Lima Bean *Per Cent*
Rosin residue, type III		5
Sardine oil, blown	11.7	7.5
Agar-agar	8.3	
Menhaden oil, blown		15
Latex	30	
Castor oil, blown	33.3	
Apple wax	40	
Flour, raw	70.5	
Menhaden oil, raw	74.5	50
No sticker	92	92.5

on the other group after they had been washed. From the ratio of these two results the percentage loss was calculated. The first two leaves of potted string beans and lima beans were used for the tests, and were forced to grow very large by pinching off the third leaf as soon as it appeared. Eight pots, each containing two or three good plants, were chosen, and the area of the leaves was measured by comparison with a series of templates of known area. It is not difficult to choose four pots of plants whose combined leaf area is very nearly equal to that on four others. The plants were then placed on a rotating table and passed eight times through a fine spray directed toward the upper surface of the leaves. Each plant was rotated through a quarter turn as it passed through the spray. A 1 per cent suspension of derris in combination with .5 per cent sticker was applied at 15 pounds pressure with the same paint gun used to spray the glass plates in the preliminary tests.

The plants were dried over night and then half of the leaf area in each determination was washed. The string beans were washed by allowing 4 liters of water at 77° F (25° C) to fall on each pot from a perforated can placed three feet above the leaves, which required about 5 minutes. Owing to their large size, the lima bean leaves were removed from the plants and each leaf was washed separately with 2 liters of water at the

[3] **Gross, C. R.** and C. M. Smith, 1934. Colorimetric method for determination of rotenone. Jour. Assoc. Off. Ag. Chem. 17:336–9.

same temperature, about 3 minutes being consumed. After being dried, equal areas of washed and unwashed leaves were placed in flasks, covered with chloroform or ether, and left over night. Better results were obtained with chloroform, because less chlorophyll was extracted from the leaves. The extract was then evaporated to dryness on a water bath and the residue in acetone was filtered into a 25 cc. volumetric flask. The relative quantity of derris on the leaves was then determined by the Gross-Smith method.[3] The amount of derris removed from the leaves is given in table 2.

Discussion and results.—Asphalt emulsion was a good sticker but the black color was objectionable; agar-agar was difficult to prepare and too costly to be used in a commercial spray; latex decomposed rapidly in sunlight; and the oils increase the rate of deterioration of derris in sunlight. Rosin residue seemed the most satisfactory sticker. This material is cheap, noninjurious to foliage, and does not decompose derris.

Rosin residue is the sticky resinous material that remains in the stills after the distillation of rosin. It is available on the market in three grades. The least viscous (type I) appears to be the most satisfactory for use as a sticker for derris, because it is the most easily emulsified. The physical constants of this grade of rosin residue are as follows:

Melting point	30° C (86° F)
Specific gravity at 25° C (77° F)	1.03
Viscosity, Saybolt at 100° C (212° F)	100–200 seconds
Acid number	50–75
Saponification number	89
Unsaponifiable	50 per cent
Petroleum ether soluble	3.8 per cent
Volatility with steam at 230° C (446° F)	25–35

A 50 per cent emulsion of rosin residue was prepared as follows: Four pounds of casein were dispersed in about 45 pounds of water to which 12 ounces of ammonium hydroxide (sp. gr. .90) had been added; 50 pounds of rosin residue were added slowly with violent agitation, and the agitation was continued until the material was emulsified. This emulsion has been kept without change for three months. It can be diluted with hard cold water.

Summary.—A laboratory investigation was conducted to develop a suitable sticker for derris when used as an insecticidal spray for control of the Japanese beetle. Several oils, waxes, resins, agar-agar and other materials were tested on glass plates and the most promising were then tested on bean foliage. Rosin residue, the residual material left in the still during the manufacture of rosin, when emulsified with ammonium caseinate, was found to be the most satisfactory and inexpensive sticker for derris.

Through the Director of Industrial Research of the engineering experiment station, two industrial fellowships have been recently set up in the Department of Zoology and Entomology of the Ohio State University. One is a project with the Sherwin-Williams Company, on which Dr. Harold Waters is carrying on research; another by the Hallowax Corporation, on which Mr. Albert C. Miller and Mr. H. E. Morrison are conducting research.

BARIUM CARBONATE FOR THE BEAN BEETLE

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Barium carbonate is produced by the Barium Reduction Corporation of Charleston, W. Va., and has been very extensively marketed under the trade name *Baricide* as an insecticide for the control of the Mexican bean beetle. Its use has grown to such proportions that we have frequent inquiries as to the value of the material from prospective users in our own and in adjoining states. The manufacturers also desired a statement of the value of *Baricide* as compared with other materials used for the same purpose since they found that many gardeners were hesitant about the use of any material not recommended by the experiment station. It is only fair to add that the manufacturers, like most responsible concerns, were anxious not to make misleading claims for their product.

Our first contact with barium carbonate was in the predepression days when the bean beetle first developed into an important pest in the state. Comparison of the material with others then used indicated that the barium compound had little value, consequently the tests were discontinued. In the search for new business necessitated by depression conditions the company revived the idea of using the barium carbonate as an insecticide and prepared improved forms of the material for that purpose. In these the physical condition was bettered and some admixture of other substances was made to promote suspension in the water and adhesion to foliage; the exact nature of the mixture is not made public but only a small proportion of foreign materials is included in the mixture. Just at this time, also, the agitation against arsenical and fluorine compounds on account of the danger from the residues caused many people to look for some nonpoisonous material and barium carbonate found ready sale; a remarkable proportion of the users report themselves as entirely satisfied with the results and the sale has steadily grown.

No official statement has been secured from the federal authorities as to barium residues; presumably they are not objectionable although the use of barium carbonate in rat poisons would lead one to suppose that it might have toxic properties when consumed by man.

Experimental work carried on under the observation of the writer during the seasons of 1934 and 1935 has included laboratory tests at Morgantown, and field tests at Morgantown and also at Kearneysville under the direction of Mr. Gould.

Laboratory tests showed *Baricide* to be rather slowly fatal to bean beetles and their larvae, toxic to blister beetles and to potato beetles, with uncertain results on some flea beetles and nymphs of grasshoppers. Several species of caterpillars ate the poison in laboratory tests without apparent effect; field tests against cabbage butterfly larvae and cabbage loopers likewise showed no protection to the infested plants; fall webworms were resistant and no other caterpillars tested have shown any definite ill effects.

Field tests carried on by Mr. Gould show *Baricide* to compare favorably with standard bean beetle poisons; only one or two per cent difference in killing power being recorded. At Morgantown in 1934 and 1935 we have had similar results. On small plots it seems unsafe to evaluate results closer than by five per cent steps. On this basis I can say that no one of the tests with *Baricide* except at low strengths showed results worse than ten per cent below the best materials in the series of tests. *Baricide* was rather definitely within 5 per cent.

Value of the materials was established by a combination of methods; inspection of the plots by persons not acquainted with the treatments; counts of beans and of feeding areas on the beans; counts of larvae and adults on the plants and counts of dead insects on the ground; inspection of the plots after harvest and weight of the plants after harvest. In the latter case average weight per hill was determined by cutting off and weighing 100 hills from each of the treatments.

In a limited series of tests it is not desirable to draw conclusions as to the absolute value of any material. Comparative values may be more definitely established. It may be said with certainty that *Baricide* does not equal the best of the standard materials such as magnesium arsenate and some of the fluosilicates; it must also be said that the difference, measured in the control only, is not great, and that satisfactory control, in moderate infestations at least, may be secured with *Baricide*.

Why, then, should we not recommend *Baricide*? There are several reasons; the first one is cost. While the material sells for only five to ten cents per pound or even less, in quantity it is one of the most expensive of treatments because of the amount required. The manufacturers advise the use of one-fourth to one-half pound to the gallon of water; we have found that one pound to the gallon gives the best control but that one-half pound or even one-fourth pound give nearly as good control commercially speaking, even though there is an apparent difference in favor of the more highly concentrated mixture.

A second disadvantage is that the quantity used makes a spray which is difficult to apply; it requires constant agitation and tends to clog the nozzles; also it requires more liquid to secure coverage than do some of the other materials used. Adhesiveness is not nearly so good as with the standard materials.

The material used as a dust is applied without a carrier; this makes it expensive and the expense is enhanced by the fact that coverage is poor and much more of the *Baricide* is required per unit area than of the standard dusts. Adhesiveness of the dust is not good and frequent applications are necessary to keep the foliage covered. Still another disadvantage of the dust is the fact that it is strongly hygroscopic and can not be used, after exposure to moist atmosphere, without first being dried.

It would appear that *Baricide* may be recommended only where cost of material and amount of labor required are not important factors and where poisonous residues are particularly objectionable. Such conditions obtain with a great number of growers of beans; therefore, it seems that there may be a definite place for the new material, with all its limitations, in our list of insecticides for bean beetle control.

FEEDING AND UTILIZATION OF SUCROSE SOLUTIONS BY POTATO FLEA BEETLE AND FALL WEBWORM

FEEDING INSECTICIDES TO FLEA BEETLE

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Artificial feeding of liquids to species (*2*, *3*) or groups (*1*) of insects having sucking mouth parts has been reported. In so far as is known artificial feeding of materials of known composition to massed groups of insects with biting mouth parts has been done only with materials which were in a more or less solid state.

Experiments have been carried out in cages similar to those described by Carter (*1*) using the potato flea beetle, *Epitrix cucumeris*, and the fall

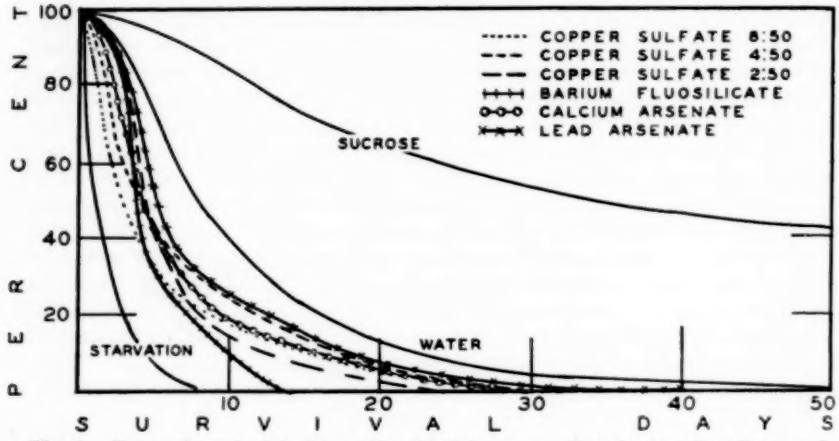

Fig. 1.—Rates of survival, in days, of beetles fed copper sulfate, barium fluosilicate, calcium arsenate and lead arsenate.

webworm, *Hyphantria cunea*, as experimental subjects. Different materials were tested for cappings of the test tubes, such as thin rubber sheeting, Cellophane, and two thicknesses of 25-mesh muslin cloth. In tests where the thin rubber sheeting was used, flea beetles apparently starved to death because they never lived more than three or four days. This was comparable to the average length of life in the starvation cages, which was $2.1 \pm .6$[1] days from a total of 367 beetles covering several repetitions over two years of experiments. In preliminary experiments where food materials were given beetles through membranes of thin (.0012 inch) Cellophane, the beetles seemed to tear into the cappings until the materials leaked out. This appeared to be particularly true where 25 or more beetles were enclosed in one cage. Cellophane also seemed to be adversely

[1] Standard error of the mean.

affected by variations in moisture, temperature and barometric pressure. Comparative feeding tests indicated that the beetles lived longer when they took food materials through cappings of muslin cloth. The average length of life of 331 beetles which fed through Cellophane was 8.4 ± 1.2 days. The average length of life of 307 beetles fed distilled water through two thicknesses of 25-mesh muslin cloth was 10.9 ± 1.4 days.

The value of this feeding technique is illustrated in some studies to determine the toxicity of stomach poisons. The materials used were proprietary brands of insecticides commonly sold for spraying purposes.

Table 1.—Materials tested, average survival of beetles, standard error of the mean, and the total number of beetles used.

Material	Total Number of Beetles	Average Survival Times in Days
Barium fluosilicate	327	$4.5 \pm .6$*
Copper sulfate 8:50	316	$5.4 \pm .8$
Copper sulfate 2:50	288	$5.9 \pm .9$
Calcium arsenate 2:50	330	$6.8 \pm .8$
Copper sulfate 4:50	354	6.9 ± 1
Lead arsenate 2:50	395	8.1 ± 1.1
Check Cages		
Starvation	367	$2.1 \pm .6$
Water	307	10.9 ± 1.4
Sucrose solution 20%	365	36 ± 3.6

* Standard error of the mean.

Barium fluosilicate, calcium arsenate, lead arsenate, and copper sulfate were fed at rates of 2 pounds per 50 gallons of water. Copper sulfate was also fed to potato flea beetles at strengths of 4 and 8 pounds per 50 gallons of water. Three types of control or check cages were used; these were starvation, water, and 20 per cent sucrose solution. The results of these studies are shown in table 1 and fig. 1.

The sucrose solution was highly significant over all other materials in sustaining life. It appears to be utilized by the beetles. The starvation check significantly shortened the life of the beetles while they lived not quite as long on water alone as where sucrose solutions were given. Comparisons of the water check and the inorganic salts or poisons are interesting. The differences between the average length of life of beetles given lead arsenate, copper sulfate 4:50, and calcium arsenate and the water check were not great enough to be outside chance occurrence. The copper sulfate solutions 2:50 and 8:50 and barium fluosilicate were significantly toxic to the beetles in comparison with the water check. In the cases of the more toxic of the materials tested, barium fluosilicate and copper sul-

Table 2.—Comparative survival of beetles treated externally with insecticides.

Material	Total Number of Beetles	Average Length of Life in Days
Calcium arsenate and Bordeaux spray	187	7.1 ± 1.3
Bordeaux alone spray	279	8.3 ± 2.1
Calcium arsenate–copper–lime dust	295	8.5 ± 1.8
Lead arsenate and Bordeaux spray	192	9.1 ± 1.2
Barium fluosilicate and Bordeaux spray	265	10 ± 1.4
Check, water spray	297	12.5 ± 1.4

fate 8:50, the mortality was nearly equal in rate to the starvation check. Copper sulfate 2:50 appeared slightly more toxic than at 4:50 but the difference was not great enough to be outside of chance occurrence. These data suggest that the lead arsenate was rather slow in its toxic action. This might be attributed, in some degree at least, to the greater insolubility and settling-out of the lead arsenate material in water.

Bordeaux mixtures of 5–5:50 alone, and combined with barium fluosilicate and with calcium and lead arsenates were sprayed on caged beetles. Other groups of beetles were dusted with calcium arsenate–copper–lime dust in a ratio of 1–1–4. Enough material was applied to cover each beetle.

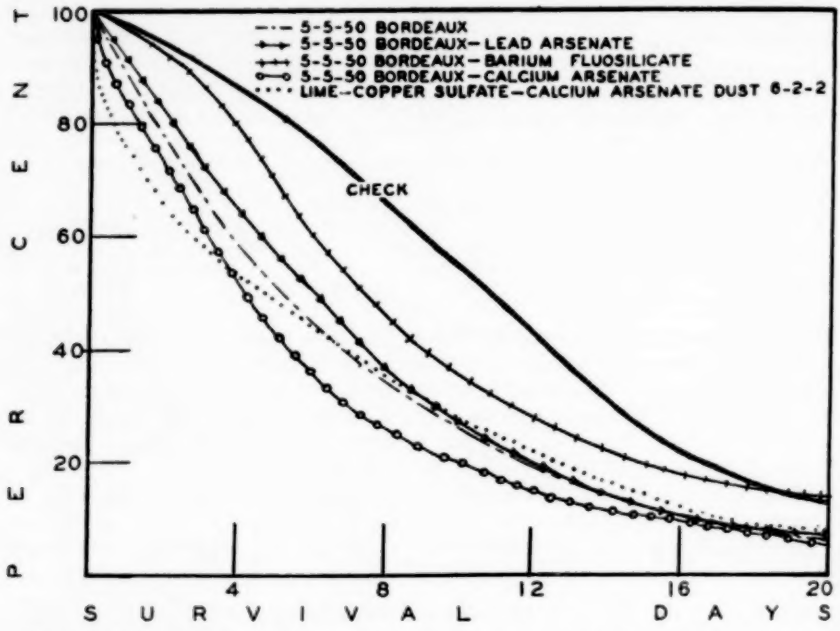

Fig. 2.—Rates of survival time, in days, of beetles sprayed or dusted, after which they were enclosed in cages with water feeders. The spray and dust materials are keyed above.

The check beetles were sprayed with water. After treatment the beetles were transferred to clean cages with water feeders.

Calcium arsenate combined with Bordeaux gave a statistically significant difference in which the average length of life was of shorter duration than the check. It was the only treatment which gave a difference over any other treatment outside chance occurrence.

Figure 2 is a graphic representation of the rates of mortality of flea beetles treated externally with stomach poisons. Attention may be drawn to the dust treatments applied to beetles which caused a high death rate the first day. Calcium arsenate combined with Bordeaux caused a high rate of mortality. Bordeaux mixture alone was quite toxic.

Maintenance of life of the fall webworm, *Hyphantria cunea*.—The average length of life of lepidopterous larvae has been maintained apparently for several days by using a 20 per cent sucrose solution. Very young larvae of the arctiid *Hyphantria cunea*[2] were enclosed in a jar in which was suspended an inverted cloth-covered vial that contained sucrose solution. Several larvae were placed in an empty jar as a starvation check. The larvae in both fed and unfed groups spread webs to all parts of the jars. The larvae were observed apparently feeding at the wet cloth covering the mouth of the vial of sucrose solution.

After an eight-day period the dead and live larvae, in both fed and starvation check jars, were counted. In the jar which contained the sucrose solution 35 (79.6 per cent) of 44 larvae were alive. There was one alive (2.8 per cent) of 36 larvae placed in the starvation check. A third group of larvae, which remained in a culture dish after the above fed and starvation groups were removed, is also comparable as a starvation check since no food material was present. Of these larvae three (2.7 per cent) were alive and 108 were dead.

Observations indicated that the larvae alive at the end of the eight-day period had diminished in thicknesses and lengths of bodies. It appears that the differences in the numbers alive in the fed and the unfed groups must be credited to consumption of the sucrose solution. One other alternative appears possible in that evaporation from the vial with sucrose solution raised the relative humidity in the jar. This increase in relative humidity, however, appears unlikely to account for all the difference in length of life of the larvae.

Some of the innumerable advantages of being able to maintain live insects which have biting mouth parts on materials in solutions may be suggested, such as the following: nutritional studies, toxicity tests, transporting or shipping live insects, and sustaining life to make habit studies or to aid in life-history studies.

Summary.—A method of feeding liquids to insects with biting mouth parts has been used which seems to have been successful. The potato flea beetle, *Epitrix cucumeris* Harr., lived considerable longer on sucrose solution than water alone, and longer on water than in the starvation check. Barium fluosilicate was the most toxic of the inorganic poison materials tested. Beetles sprayed and dusted with Bordeaux mixtures, alone and in combinations with some common stomach poisons, lived almost as long as those in the water check. Beetles sprayed with 5–5:50 Bordeaux combined with calcium arsenate, however, did not live as long as those in the water check.

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[2] Determination was made by Dr. W. T. M. Forbes, of the Department of Entomology, Cornell University.

PERSISTENCE OF TOXICITY OF NICOTINE-BENTONITE ON APPLES[1]

WARREN MOORE, *Bon Air, Va.*

The toxicity of nicotine-bentonite was not destroyed by sunlight. The persistence of toxicity of nicotine-bentonite on apples compared favorably with that of arsenate of lead-lime-milk.

Chemical.—It is known that ultra-violet radiations will cause destructive oxidation of nicotine. Last winter Mr. Ralston found that nicotine fixed on bentonite was in large measure destroyed when irradiated with an "Uviarc" mercury arc lamp. The addition of tannic acid reduced the decomposition. The radiations from this lamp are of a higher potential range than those reaching the earth's surface from the sun. Therefore, conclusions as to the effect of sunlight could not be drawn. Accordingly, thin films of nicotine–bentonite on the inside surface of quartz containers with free access of air were exposed outdoors in a sunny place from February to March. From two trials, 83 and 78 per cent of the original nicotine was recovered after 90 days. Consequently, it was desired to determine biologically whether under field conditions fixed nicotine was destroyed by sunlight.

Table 1.

Tree	Relative Size	Variety	Crop 1935	Spray Formula per 100 Gals.
1	Largest	Winesap	13 bu.	Bentonite 5 lbs., *Black Leaf 40* 1.1 lbs., dry skim milk 3.5 oz.
2	Smaller	Winesap	5 bu.	Same plus 1.7 lbs., tannic acid
3	Smallest	Black Twig	1½ bu.	Lead arsenate 3 lbs., lime 5 lbs., dry skim milk 3.5 oz.

Biological.—It was reasoned that an apple uniformly coated with an adherent film of insoluble, photostable insecticide should lose toxicity at about the same time rate on the sunny and shady sides. It was proposed to compare over a period of time the toxicity of the pink side of sprayed apples with that of the opposite (green) side. The procedure assumes that the color is greatest on the area of maximum illumination and that an area diametrically opposite will be that which has received the least illumination.

Three apple trees standing together in an open field were selected and pruned for the experiments. This row of three trees ran north and south. Tree Number 1 was at the south end. Each received six cover sprays, 15 gallons per spray, applied with a barrel sprayer having a long spray rod. *Kopper's Flotation Sulfur* was added to the first two cover sprays. The cover sprays were applied about 10 days apart from May 9 to July 3.

Technique.—Laboratory study of apples from these trees was begun in June. Rings about 3 mm. thick were cut from soft rubber tubing of 7 mm. bore. A ring was placed on the most colored area of the apple, an

[1] Contribution from Research Department, Tobacco By-Products & Chemical Corporation, R. B. Arnold, chief of research. Acknowledgments are also due to Williams Ralston, chemist, and to Forrest Daniels, technician. E. H. Siegler kindly criticized the manuscript.

egg of codling moth, *Carpocapsa pomonella* L., was put inside, the opening covered with a small square of paper, and the whole attached to the apple with adhesive tape. The apple was turned over and the operation repeated on the opposite area. In carrying out the method it was found convenient to cut lengths of half-inch tape equal to about one and one-

Table 2.—Per cents of larvae causing injury, and per cents of apple areas entered on pink and on green sides of apples sampled June 22, 1935.

	Per Cent Injuring	Per Cent Entry
Nicotine–bentonite		
Pink	77	51
Green	97	70
Nicotine–bentonite plus tannin		
Pink	65	43
Green	80	60
Lead arsenate		
Pink	91	
Green	94	
No Spray		
Pink	100	
Green	100	

half times the circumference of the apple. The small square of paper and a rubber ring were affixed near one end of the strip and an egg placed in the recess. The apple was pressed down on the ring and the tape pressed against the apple on both sides. A second ring, egg and paper were now placed on the opposite (top) side of the apple and the whole bound tightly with the tape. With some practice, it became possible to confine practically all larvae to the small cell formed by the apple, the inner surface of the rubber ring and the paper cap.

Distribution of toxicity.—Samples drawn in June were almost invariably more toxic on the pink side. This difficulty was least marked

Table 3.

	Pink Side		Green Side		All
	Number Apples	Entry	Number Apples	Entry	Per Cent Entry
Heavy deposit	9	0	2	0	0
Medium deposit	23	14	17	9	57
Light deposit	5	5	18	17	96
Total	37	19 (51%)	37	26 (70%)	

on tree Number 3, which was much more open than the others. The inequality seemed to be due to the fact that the exposed sides of the apples received the most spray. Visible spray deposit was often absent from the unexposed sides. For example, the results from tests of 30 apple samples taken June 22 are tabulated in table 2.

When these apples were examined for injury, the visible deposit inside each ring was recorded as heavy, medium or light. Tabulation of the observations on the nicotine–bentonite-sprayed apples yields the information of table 3.

The preponderance of heavier deposit on the pink side seems to account for the difference in toxicity.

Following the fourth cover, trees 1 and 2 were thinned to facilitate spraying from the inside and a special effort was made to spray for uniform coverage. Progress was indicated by samples taken after the fifth cover. Samples following the sixth and last cover (July 3) seemed to have as uniform coating as could be hoped for. A heavy coating on both

Table 4.—Comparison of pink and green areas of apples sprayed July 3, 1935.

Sample Date	7/3	7/9	7/10	7/11	7/30	7/31	8/1	Averages I. All	II. Days 2, 6, 7, 8	III. Days 27, 28, 29	Increase III over II	Difference Pink—Green
Days Since Spray	2	6	7	8	27	28	29					
Per Cent of Larvae Injuring												
Nicotine–bentonite												
Pink	22	31	36	27	43	28	79	38	29	50	21	
Green	20	38	33	30	37	39	79	39	30	52	22	−1
Same plus tannin												
Pink	19	18	19	23	52	30	44	29	20	42	22	
Green	9	17	11	31	38	21	36	23	17	32	15	7
Lead arsenate												
Pink	93	100	100	100	100	100	100	100				
Green	97	100	100	100	100	100	100	100				
No spray												
Pink	100						100	100		100		
Green	100						100	100		100		
Per Cent of Larvae Entering												
Nicotine–bentonite												
Pink	22	29	29	24	43	28	79	36	26	50	24	
Green	17	36	19	30	37	37	79	36	25	51	26	−2
Same plus tannin												
Pink	16	16	13	18	48	26	44	26	16	39	23	
Green	9	15	4	27	29	15	34	19	14	26	12	11
Lead arsenate												
Pink	48	50	64	67	93	80	89	70	57	87	30	
Green	35	43	49	60	90	82	91	64	47	88	41	−11
No spray												
Pink	100						100					
Green	100						100					
Number apples each treatment	37	50	50	50	50	50	50	337	187	150		
Rainfall, inches, cumulative from 7/3	.04	.64	.80	.80	2.74	2.74	2.74				1.94	
Sunshine, hours, cumulative from 7/3	17	38	45	54	204	219	225					

the green and pink was recorded for every apple in the samples taken July 5. From this point the data on loss of toxicity were recorded. Apple samples were removed to the insectary from time to time until August 1, and tested as already described. In table 4 the results are recorded as per cent of larvae (hatched eggs) causing injury, and as per cent entering. The rainfall data are from a gauge on the premises. The sunshine record is calculated from the report of the Richmond station of the U. S. Weather Bureau, about 8 miles distant. Sunshine for July was 55 per cent, the normal being 67 per cent.

There is, of course, considerable random variation. In table 4, column 10, the values for the second, sixth, seventh and eighth days after spraying are averaged, while column 11 is the average for the twenty-seventh, twenty-eighth and twenty-ninth days. In all cases there is the expected loss of toxicity, but the pink side of the nicotine apples has held up well as compared with the opposite side—and as compared with the pink side of the arsenate of lead apples. It is concluded that photochemical decomposition was a negligible factor in this loss of toxicity.

Comparison of nicotine and arsenate of lead.—The data in table 4 indicate a superiority of the tank-mixed nicotine–bentonite to arsenate of lead–lime–milk as to both injuries and entries. It was questioned whether this was an apparent difference due to the technique, and whether the difference would persist for longer periods.

Table 5.—Comparisons of toxicity of apples sprayed July 3, 1935, lead arsenate on Black Twig, nicotine-bentonite on Winesap. Figures indicate the per cent of larvae (hatched eggs) causing injury. In the case of lead arsenate the percent of living larvae is also given.

Sample Date Days Since Spray	8/14 42	8/15 43	8/16 44	8/23 51	Average or Total
High Humidity					
Per cent injury, no spray	85		76	81	81
Per cent injury, nicotine–bentonite	37	38	37	31	36
Per cent injury, lead arsenate	81	60	70	65	69
Per cent wormy, lead arsenate	47	40	45	47	45
Normal Humidity					
Per cent injury, no spray	76		80	78	78
Per cent injury, nicotine–bentonite	24	35	36	37	33
Per cent injury, lead arsenate	46	42	62	50	50
Per cent wormy, lead arsenate	34	33	40	37	36
No. of apples in each category	30	30	16	30	106
No. of eggs in each category	150	150	80	150	530

To test these questions, samples were taken from trees 1 and 3 during the latter half of August. Using codling moth larvae as indicators, these apples were tested for toxicity under two different sets of conditions. To the stem of each apple five eggs on wax paper were affixed with a pin. For the high-humidity tests, half of each sample was put in battery jars with glass covers. For the normal-humidity tests, W. S. Hough's technique was imitated. The apples were suspended from the ceiling of the insectary, and an unsprayed apple leaf was fastened on top of the eggs.

The observations are given in table 5. For nicotine–bentonite only the per cent injury is given, since it does not differ appreciably from the per cent wormy. For arsenate of lead–lime–milk both per cent injury and per cent wormy are given, since these two values diverge widely in the case of that insecticide.

It will be seen that the toxicity of the nicotine–bentonite apples compares favorably with that of the arsenate of lead apples some six weeks after spraying. It is unfortunate that both treatments were not applied to the same variety.

Conclusions.—Photochemical decomposition seems to be a negligible factor in loss of toxicity of apples sprayed with nicotine–bentonite, at least in humid regions.

Field comparisons of tank-mixed nicotine–bentonite and arsenate of lead usually indicate the presence of more wormy apples on the nicotine-sprayed trees. We may doubt that this is due to inferiority of the nicotine treatment as to toxicity, or as to persistence of toxicity.

RELATIVE TOXICITY OF SOME OPTICALLY ACTIVE AND INACTIVE ROTENONE DERIVATIVES TO CULICINE MOSQUITO LARVAE

DAVID E. FINK and H. L. HALLER, *U.S.D.A., Bureau of Entomology and Plant Quarantine*[1]

Although rotenone is regarded as probably the most important insecticidal constituent in derris extractives, previous investigators (*1*, *7*) have shown that other compounds of perhaps equal toxicity are present. However, tests (*3*, *9*) of the other three well-characterized crystalline compounds that have been prepared from derris extracts—deguelin, tephrosin, and toxicarol—have indicated that deguelin possesses insufficient toxicity to account for the effectiveness of derris extractives, while the other two compounds are of a still lower order of toxicity. As isolated from derris extractives, deguelin, tephrosin and toxicarol are optically inactive, whereas rotenone is optically active. Recent experiments (*6*) have shown that deguelin is present in the extractives in important quantities and, indirectly, that at least part of it is in optically active form. Therefore, if evidence could be obtained to show that optically active deguelin and other derivatives of rotenone are more toxic than the corresponding inactive forms, the high toxicity of the constituents of derris extractives other than rotenone would become more readily understandable.

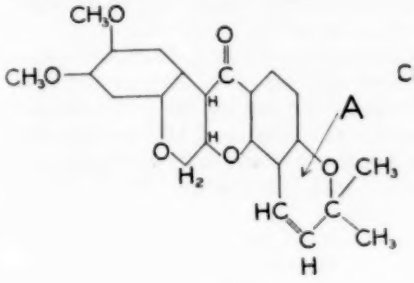
It would be desirable to obtain direct evidence on this point by comparing the toxicity of the optically active and inactive forms of deguelin, but all attempts to isolate an optically active form have failed. However, its optically active dihydro derivative can be isolated, and the toxicity of this compound and its inactive form can be compared. Such a comparison was made by Gersdorff (*5*) against goldfish. An optically inactive form of rotenone has not yet been prepared, but optically active and inactive forms of isorotenone (*6*) have been made.

The present experiments deal with the relative toxicity of optically active and inactive forms of dihydrodeguelin and isorotenone to culicine mosquito larvae. Rotenone and deguelin were included in the tests for the purpose of comparison.

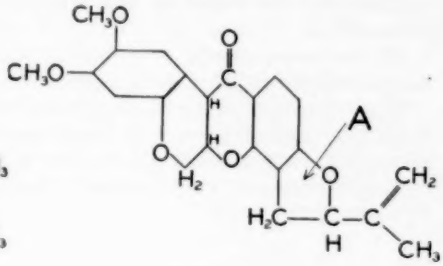
Chemistry of compounds tested.—The preparation and determination of the structures of the compounds tested have been described

[1] The writers acknowledge the assistance of F. L. Campbell, Division of Control Investigations, in preparation of the manuscript for publication.

elsewhere (*8*). The relationship among them can best be illustrated by reference to the structural formulas of rotenone and deguelin:



Deguelin



Rotenone

Rotenone differs structurally from deguelin only in that ring A is a substituted dihydrofuran nucleus, whereas in deguelin it is a 2-substituted alpha pyran ring.

According to the number of asymmetric carbon atoms, three in rotenone and two in deguelin, there are eight possible optically active forms of rotenone and four of deguelin. However, only one optically active form of rotenone and none of deguelin are known.

Isorotenone differs structurally from rotenone in the position of the double bond; in rotenone this bond is in the aliphatic side chain attached to ring A, whereas in isorotenone it is within ring A. Thus isorotenone is a furan derivative.

The isorotenone derived from rotenone is optically active. On treatment with alkali in an atmosphere of hydrogen it is racemized to yield *dl* isorotenone, which is optically inactive (*6*).

Dihydrodeguelin differs from deguelin only in that the double bond in ring A has been saturated. When derived from rotenone through optically active rotenonic acid, it is optically active. When, however, the rotenonic acid is first refluxed with alkali and then isomerized to beta dihydrorotenone, an optically inactive product is obtained which is identical with that produced by the hydrogenation of ordinary inactive deguelin.

Insecticidal tests.—The tests were made in the laboratory[2] of the Bureau of Entomology and Plant Quarantine at Orlando, Fla., where *Culex quinquefasciatus* Say is the predominant culicine species. Eggs laid by wild mosquitoes were collected daily from tubs containing manure water. About 25 egg rafts were placed on the surface of a yeast suspension (*2*) in 3-liter battery jars. When the larvae hatching from these eggs reached the third instar they were transferred to clean battery jars containing fresh yeast suspension. This served the dual purpose of eliminating scum and of supplying fresh food to the developing larvae.

Fourth (last)-instar larvae were used for the tests. They were transferred from one container to another, washed, and counted with the aid

[2] The senior author is indebted to the Division of Fruit Insect Investigations for facilities provided at the Orlando laboratory.

of cheesecloth nets. For each test 50 larvae were washed into a 100 cc. beaker with 100 cc. of the solution or suspension to be tested. Each beaker was then placed immediately in a water bath at $27 \pm .06°$ C ($80.6 \pm 1.08°$ F).

All six compounds were tested simultaneously, and four tests were made of each at 10 concentrations ranging from 1 to 10 mg. per liter.

The toxicity of a given compound was measured by the time elapsing from the beginning of the treatment to the death of the twenty-fifth larva (50 per cent mortality). Affected larvae usually sank to the bottom of the beaker but some floated after becoming immobile. To determine

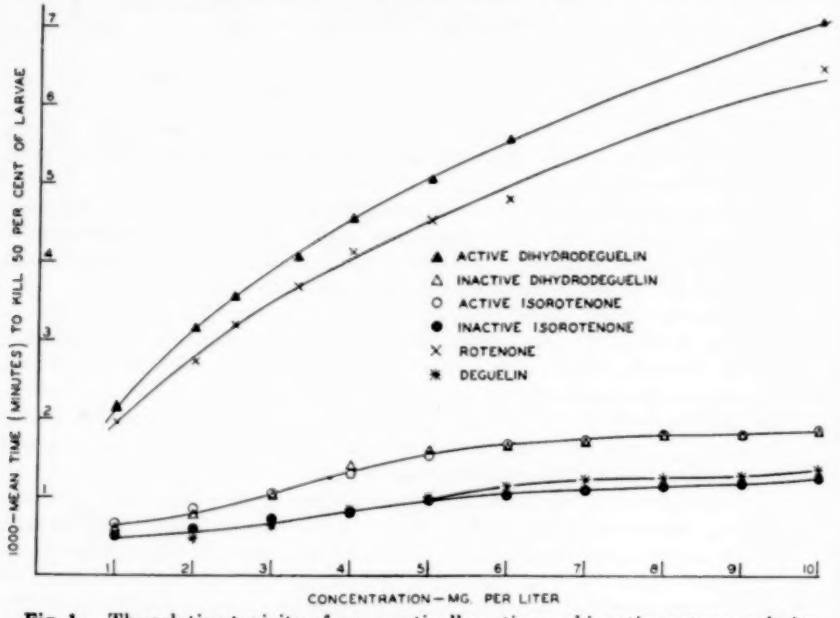


Fig. 1.—The relative toxicity of some optically active and inactive rotenone derivatives to culicine mosquito larvae.

whether immobile floating larvae were actually dead, they were removed by means of a medicine dropper to separate small beakers. If the larvae wriggled after the test solution was removed from the small beakers they were replaced in the large beaker.

For preparation of the solutions of suspensions to be tested, 50 mgs. of each compound were dissolved in 25 cc. of acetone and the solutions were kept in a refrigerator until needed. Calculated volumes of these stock solutions were pipetted into distilled water in a beaker, the resulting solution or suspension being made up to 100 cc. In all dilutions the percentage of acetone was made uniform (.5 per cent by volume) by the subsequent addition of the required volume. Preliminary tests showed that the larvae would tolerate as much as 1.5 per cent of acetone by volume.

As all compounds tested were insoluble in water, the addition of acetone solutions of them to water resulted in more or less cloudy suspensions at concentrations above 5 mg. per liter. Below this concentration the liquid appeared to be clear, but it is not certain that the compounds were in true solution. At the higher concentrations all compounds remained in suspension for at least eight hours. Optically active and inactive isorotenone flocculated after eight hours, settling gradually.

Results.—The results of these tests are shown in fig. 1, in which concentration is plotted against the reciprocal of the mean time to kill 50 per cent of the larvae. Fifty per cent mortality was attained at all concentrations except 1 mg. per liter of deguelin, in which no mortality occurred after 35 hours exposure and pupation of the larvae began. In low concentrations of other compounds a few pupae occasionally formed before the 50 per cent point was reached. No deaths occurred in the distilled-water checks that were included in each series of tests.

From fig. 1 the reader can get a general impression of the relative toxicity of the six compounds.[3] The essential point demonstrated is that optically active compounds are more toxic than the corresponding optically inactive compounds at all concentrations tested. The same result was reached by Gersdorff (*5*) in his tests against goldfish. If optically active deguelin exceeds in toxicity the inactive form to the same extent that the active dihydro derivative exceeds its inactive form, then it will be reasonable to attribute the hitherto unaccountable toxicity of derris extractives to optically active deguelin.

Summary.—Nearly full-grown culicine mosquito larvae, principally *Culex quinquefasciatus* Say, were used as test insects to compare the toxicity of rotenone, deguelin, optically active and inactive dihydrodeguelin, and optically active and inactive isorotenone, the chemical relationships of which are discussed. Optically active dihydrodeguelin and isorotenone were more toxic than the corresponding optically inactive forms. It is therefore probable that the hitherto unaccountable toxicity of derris extractives can be attributed partly to the optically active deguelin known to be present.

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(*5*) ———— 1935. The toxicity of optically active and inactive dihydrodeguelins. Jour. Ag. Res. **52**:355–61. Illus.

[3] The criterion of the minimum *ct* product, as proposed by Gersdorff (*4*) for obtaining a numerical expression for relative toxicity, could not be applied, because no minima were observed in the region of concentrations which were tested. In this respect these mosquito larvae differ from those used at Takoma Park, Md., in experimentation on the detoxication of rotenone by light (*7*), for in that case a curve with a minimum *ct* value was obtained with rotenone.

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DOSAGE-MORTALITY CURVE OF PYRETHRUM SPRAYS ON THE HOUSE FLY

MUSCA DOMESTICA L.

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The percentage of kill obtained by a definite amount of the active principles of pyrethrum is not a fixed figure. This toxicity per active principle or pyrethrin content varies between wide limits depending on the biological and chemical technique of the laboratory making the test. The original Peet-Grady (*2*) test is known to most entomologists, but modifications and its subsequent adoption as a standard for the evalua-

Table 1.—Biological and chemical data for the dosage-mortality curve.

	Sample									
	10	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
Pyrethrin I *g/100 cc.*	7.6	15.3	23.7	28.3	32.4	37.5	42.1	43.6	49.7	55.9
Pyrethrin II *g/100 cc.*	10.1	20.2	29.1	34.8	39.8	46.1	51.8	53.6	60.3	68.8
Pyrethrins total *g/100 cc.*	17.7	35.5	52.8	63.1	72.2	83.6	93.9	97.2	110	124.7
Number flies used	1829	1810	1750	1891	1715	1795	1765	1801	1821	1792
Maximum: Per cent down in 10 min.	86	92	99	99	99	100	100	100	100	100
Maximum: Per cent kill in 24 hrs.	28.3	33.1	44.8	51.8	60.5	62.7	68.3	68.5	73.2	75.6
Minimum: Per cent down in 10 min.	71	81	86	90	91	93	90	93	94	95
Minimum: Per cent kill in 24 hrs.	13.2	23.2	37.1	43.9	50.4	55.3	61.9	62.1	65	68.9
Average: Per cent down in 10 min.	79	87	91	94	95	96	97	96	97	98
Average: Per cent kill in 24 hrs.	20.8	30.4	40.5	47	56.2	58.1	64.8	65.8	68.1	69.7

The oil distillate run in conjunction with these tests yielded an average kill of 5.1 per cent.

tion of liquid insecticides of the fly spray type by the National Association of Insecticide and Disinfectant Manufacturers (*1*) is probably not familiar to many entomologists. The different media used in the rearing of the flies, deviations in temperature and humidity from the standard in some laboratories, and the absence of a uniform standard solution for a check on the resistance of the insects are some of the important elements of technique which contribute to varying results of different

laboratories on the same sample. The degree of importance of these elements of technique is yet to be determined.

At present there is no standard chemical method for the estimation of pyrethrin content. The adequacy and accuracy of the chemical methods in use today are in a state of controversy, and different laboratories are in the majority of instances unable to agree in findings on the same sample.

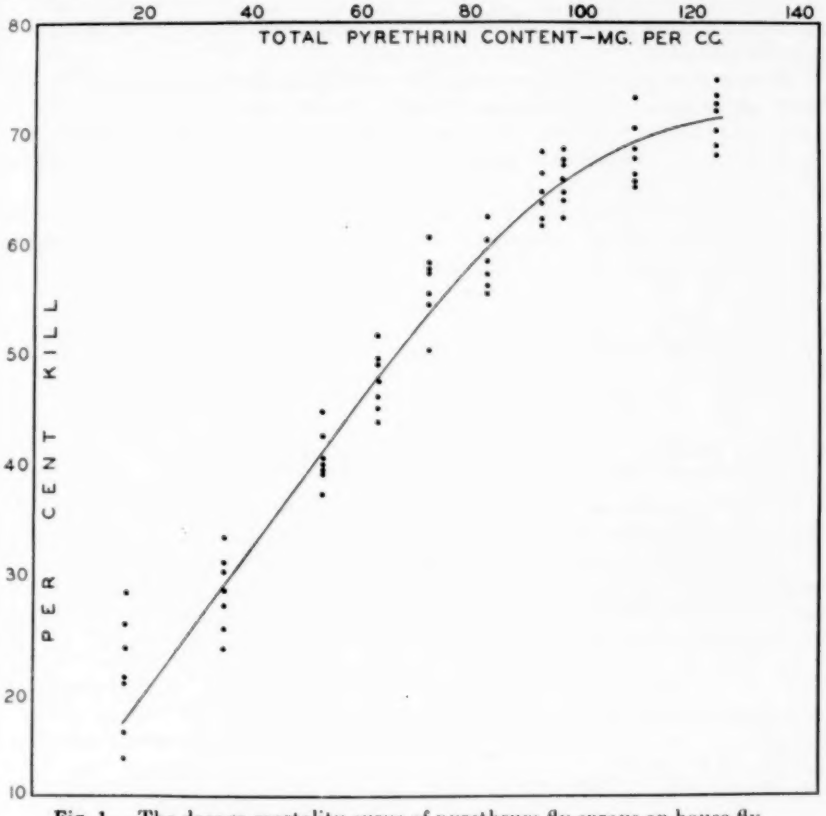

Fig. 1.—The dosage-mortality curve of pyrethrum fly sprays on house fly.

For the purpose of determining a dosage-mortality curve of pyrethrum fly sprays on the house fly, our laboratory has used the standard Peet-Grady procedure as adopted by the National Association of Insecticide and Disinfectant Manufacturers. The chemical method used was that of Dr. H. A. Seil (*3*).

It will be observed from table 1 and the graph that for a definite pyrethrin content the killing power varies on the average between plus or minus 4 per cent in this series of results. This variation is to be expected, since different batches of flies reared under as uniform conditions as possible will have different resistances. The curve which

passes through the toxic limits of each sample does not represent the mean of the killing power of each standardized sample of fly spray. It does represent, however, the trend of the relationship between pyrethrin content and killing power. The curve of toxicity of fly sprays containing less than 75 mg. pyrethrins per 100 cc. slopes downward abruptly as the pyrethrin content decreases. Consequently, in this area of concentration a small increase in pyrethrin content would give a relatively large increase in toxic effect. The converse is also true. As the pyrethrin content increases above 75 mg. per 100 cc., the increase in the percentage of kill is relatively less.

This curve includes the range in pyrethrin concentrations of commercial fly sprays on the market today. It illustrates approximately the pyrethrin content which is associated with a given percentage of kill. Conversely, it represents approximately the percentage of kill which may be expected from a given pyrethrin content.

Table 2 is presented for the purpose of approximating the toxicity to be expected from a spray based on pounds of average good quality flowers (.95 per cent total pyrethrins) extracted per gallon of oil base.

Table 2.*

Pounds of Flowers Extracted per Gallon	Pyrethrins Extracted mg–100 cc.	Limits of Estimated Percentage Kill
.5	51.3	37–45
.75	76.9	50–57
1	102.5	60–66
1.25	128.1	70–75

* An extraction efficiency of 90 per cent is assumed in these calculations.

It is to be remembered that the curve presented is based on work done in our testing unit. It is not offered as standard for comparing toxicity with pyrethrin content, since similar work done by another laboratory might show a different curve level. It is safe to say, however, that this curve does represent the general trend of the relationship between pyrethrin content and percentage kill of pyrethrum fly sprays.

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Certification of sweet potatoes has been carried on in Tennessee for the last fourteen years and has proved a very great aid. This certification is purely optional with the grower, according to the state entomologist, but the demand has been very great and nearly all Tennessee commercial growers are now asking for certification.

The phoney peach disease survey of the State of Tennessee has been in progress since August 1935. The purpose of this survey is the clean-up of all worthless peach trees in the orchards, also the escaped seedling trees. The work is in progress in the counties of Anderson, Bradley, Franklin, Hamilton, Knox, Rhea and Roane. This is a cooperative measure between the U. S. Bureau of Entomology and Plant Quarantine and the Division of Insect and Plant Disease Control. Very little phony peach disease has been in Tennessee and it is hoped that this clean-up work will completely eradicate the disease in this state.

CONSTITUENTS OF PYRETHRUM FLOWERS

III. THE PYRETHRIN CONTENT OF FRESH FLOWERS

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The isolation and identification of the active principles of pyrethrum flowers, pyrethrin I and pyrethrin II, by Staudinger & Ruzicka (*5*) and the development of quantitative methods for their determination (*1*, *4*) enable scientific studies to be made of numerous problems arising in the cultivation and handling of pyrethrum flowers.

By the application of these methods it is possible to follow variations in the pyrethrin I and pyrethrin II contents of the different plants. It has been the custom to analyze the flowers after they have been dried, and the effect of various methods of drying on the pyrethrin content has been reported by Gnadinger, Evans & Corl (*2*). From experiments using seven widely different drying methods they found that the method of drying did not appreciably affect the pyrethrin content. In these experiments the pyrethrin content was determined after the flowers had been dried. No results have been reported in the literature, so far as we know, in which the presence of the pyrethrins was demonstrated in the fresh flowers before drying.

The isolation of products, such as the pyrethrins, from plant material that has been subjected to slow drying and other treatment (exposure to air and sunlight), during which enzyme action may play an important rôle, is no reason for assuming that the isolated products existed as such in the original living tissue. Unless precautions have been taken to inhibit possible enzymic reactions, the substance recovered may be either a decomposition product or one synthesized in the process of isolation. When the substance isolated is capable of enzymic decomposition or synthesis, it is possible that the amount present in the living plant may be much greater or much less than the quantity recoverable.

Both pyrethrin I and pyrethrin II are unsaturated keto esters, and since they are readily cleaved into the alcoholic component, pyrethrolone, and the acid component, chrysanthemum monocarboxylic acid in the case of pyrethrin I and chrysanthemum dicarboxylic acid in the case of pyrethrin II, it is possible that hydrolytic enzymes such as esterases, the presence of which in some plant juices is well established, have an effect on the synthesis or decomposition of the pyrethrins.

The actions of esterases may be represented by the following schematic formula:

$$\underset{\text{(ester)}}{RCOOR'} + H_2O \rightarrow RCOOH + R'OH \quad \underset{\text{(acid)}}{} \quad \underset{\text{(alcohol)}}{}$$

As indicated, the reaction is reversible; that is, the esterases may assist in the synthesis of the esters or they may aid in the hydrolysis of the

[1] The first paper in this series by Haller & Acree, Indus. Engin. Chem. **7**:343, 1935; and the second by LaForge & Haller, Jour. Am. Chem. Soc. **57**:1893, 1935.

esters with the formation of the alcohols and the acids. The presence of pyrethrolone and chrysanthemum mono and dicarboxylic acids has been reported in the dried flowers (*3*). Their presence can be accounted for by the assumption either that the pyrethrins are formed by the esterification of the chrysanthemum acids with pyrethrolone, in which the esterases may have some part, or that the pyrethrins are partly cleaved with the aid of the esterases before the latter's destruction by the higher temperature used in drying the flowers.

Esterases are not the only means by which the pyrethrins or their hydrolytic products could disappear. Oxidases, which are also widely distributed in nature, might have some action on such highly unsaturated compounds as the pyrethrins and their hydrolytic products.

Another factor which might affect the ultimate pyrethrin content of pyrethrum flowers is the high moisture content of the fresh flowers. As is indicated in the reaction given, the removal of water would aid in ester formation. However, the hydrolysis of an ester is influenced greatly by heat. In general, an increase in temperature of 10° C doubles the rate of reaction; so that the pyrethrins might be expected to be hydrolyzed four times as fast at 40° as at 20° C.

The question therefore arises—are the pyrethrins formed in the process of drying or, if the pyrethrins are present in the fresh flowers, to what extent are they affected by enzyme activity and moisture content in the process of drying?

Of the several methods used for determining the pyrethrin content of pyrethrum flowers, the so-called acid methods have been used extensively. These methods are based on the fact that pyrethrin I and pyrethrin II yield, on saponification with alcoholic potash, chrysanthemum mono and dicarboxylic acids, respectively, which are separated and then titrated. The presence of free chrysanthemum acids in the flowers would give high results by these methods. If, however, the free acids are removed by extraction with alkali carbonate solution before saponification, the results will approach more nearly the true value of the pyrethrin content. By first extracting the petroleum–ether solution prepared from fresh flowers with alkali carbonate, it is possible to demonstrate whether the pyrethrins are formed in the process of drying or exist as such in the fresh flowers.

Experimentation.—An opportunity to undertake a study of fresh pyrethrum flowers presented itself through the courtesy of Mr. A. F. Sievers, Division of Drug and Related Plants, Bureau of Plant Industry, U. S. Department of Agriculture. Pyrethrum flowers are being grown successfully by him at the experimental farm, Arlington, Va., and through his cooperation about 20 pounds of fully open pyrethrum flower heads were obtained.

The flowers were collected on June 6, 1935, between 10:30 and 11:30 a.m., and immediately brought to the laboratory. After thorough mixing, five samples were taken at random, and the following experiments made.

Experiment 1.—The sample of flowers was dried for 24 hours in a cabinet drier. The top of the drier was provided with a short chimney while the bottom was open to permit circulation of air. An electric

heating unit was placed in the bottom of the cabinet, and two feet above it was a wire-screen tray for holding the sample of flowers. Air, maintained at 40–45° C, was forced through the cabinet by an electric fan placed at the lower opening.

Experiment 2.—A sample of flowers was placed in an ordinary gas-heated vacuum drier under 25 inches of vacuum for 48 hours while the temperature was maintained at 65–70° C.

Experiment 3.—A sample of flowers was placed for two hours in a steam sterilizer at 120° C and 15 pounds pressure. The flowers were subsequently dried with forced ventilation at 40–45° C for 24 hours in the cabinet drier described above.

Experiment 4.—A sample of flowers was covered with 6 liters of 95 per cent ethyl alcohol and allowed to stand for 20 hours. The solvent was decanted. The flowers were transferred to a percolator and covered with 3 liters of fresh alcohol. After standing seven hours, the solvent was allowed to drain off completely and was concentrated under reduced pressure to a small volume from which a quantity of oil separated. The oil was dissolved in petroleum–ether, the solution was washed with water and then dried over anhydrous sodium sulfate. On evaporation under reduced pressure 17 grams of oily material was obtained. The exhausted flowers were removed from the percolator, spread out, and partially dried at room temperature under ventilation from an electric fan. Drying was completed in the cabinet drier described above under forced ventilation of air at 40–45° C for 24 hours.

Experiment 5.—This experiment was similar to the fourth in every detail except that acetone was used as the solvent instead of alcohol. Fifteen grams of oily material were obtained.

The procedures of experiments 1 and 2 are those frequently used in the laboratory in drying pyrethrum flowers and were carried out as a check. Experiments 3, 4 and 5 were made to determine the effect of inactivating the enzymes in the fresh flowers and to establish the presence of the pyrethrins subsequent to drying the flowers. It is well known that enzymes are inactivated by sterilization and also by organic solvents such as alcohol and acetone.

In each of these experiments the samples of flowers were weighed both before and after drying, and the percentage loss of moisture was computed. In experiments 4 and 5 the weight of the oil obtained was added to the dry weight of the flowers, and this weight was used for computing the percentage loss in moisture. After drying, the flowers were finely ground and analyzed by the Seil method (*4*) for the determination of pyrethrins I and II. The alcoholic and acetone concentrates from experiments 4 and 5 were analyzed by this method.

To determine the presence of the uncombined chrysanthemum acids in the fresh flowers (since they would be determined as pyrethrins by the Seil or any of the acid methods), 2 grams of the acetone concentrate was dissolved in 200 cc. of petroleum–ether. This ether solution was extracted three times with a 10 per cent aqueous solution of potassium carbonate. One gram of *Filter-cel* and 10 cc. of a 10 per cent solution of barium chloride were added to the carbonate extract, and the volume

was made up to 200 cc. After thorough mixing, the solution was filtered, acidified and steam distilled. The residue and the distillate from this distillation were treated in the same manner as required from the same point in the procedure of the Seil method, and it was found that the 15 grams of the acetone concentrate contained .04 gram and .03 gram of chrysanthemum mono and dicarboxylic acids, respectively.

To determine the presence of the uncombined chrysanthemum acids in the dried flowers, petroleum–ether extracts were made by Soxhlet extraction of 10-gram samples of the dried flowers. These petroleum–ether extracts were extracted with alkali carbonate solution. The carbonate extracts were then treated and analyzed as above.

Results.—Table 1 summarizes the data obtained from the foregoing experiments.

The results confirm those of Gnadinger and his coworkers with respect

Table 1.—Pyrethrin content of fresh and dry pyrethrum flowers.

Experiment	Treatment	Fresh Weight	Dry Weight	Moisture Loss on Drying	Per Cent Chrysanthemum Acid Content, Dry Basis		Per Cent Pyrethrin Content, Dry Basis		Per Cent Pyrethrin Content of Fresh Flowers		Total Per Cent
		grams	grams	per cent	Mono	Di	I	II	I	II	
	Dried Flowers										
1	Screen dried	2000	515	74.2	.05	.05	.43	.30	.11	.10	.21
2	Vacuum dried	1000	209	79.1	.05	.04	.39	.34	.12	.07	.19
3	Sterilized and then screen dried	2000	520	74	.03	.03	.52	.28	.13	.07	.20
	Fresh Flowers										
4	Extracted with ethyl alcohol	2000									
	Screen-dried marc		420	78.1	.03	.02	.12	.13	.02	.02	.26
	Alcoholic concentrate		17		.01	.01	.67	.34	.15	.07	
5	Extracted with acetone	2000									
	Screen-dried marc		425	78	.02	.04	.19	.10	.04	.02	.29
	Alcoholic content		15		.01	.01	.64	.40	.14	.09	

to the effect of drying, as no differences were observed when several methods were employed. Also no appreciable difference in the pyrethrin content was observed in fresh flowers and the same material after drying. Hence the possibility of destruction or synthesis of the pyrethrins by enzymic agencies or water appears to be remote.

Summary.—A study was made of pyrethrum flowers to determine whether the pyrethrins are present in the fresh flowers, and if so, to what extent they are affected by enzyme activity and moisture content in the process of drying.

The results confirm those of Gnadinger and coworkers in that the method of drying produces very little variation in the pyrethrin content of the flowers. It is shown that the pyrethrin I and pyrethrin II exist as such in the fresh pyrethrum flowers. Enzymes and moisture have a negligible effect on the synthesis or decomposition of the pyrethrins in the process of drying the flowers.

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PYRETHRIN CONTENT OF PYRETHRUM FLOWERS FROM VARIOUS SOURCES

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Although pyrethrum flowers, *Chrysanthemum cinerariaefolium*, are cultivated in many parts of the world, only certain localities stand out as the principal sources of supply. Japan and Dalmatia are the major commercial producers. Sources of lesser importance are Kenya Colony in British East Africa, France, Bulgaria, Brazil and Russia (U.S.S.R.). The flowers grown in Russia are *Chrysanthemum roseum*. Experimental plantings are now to be found in the United States in Pennsylvania, Tennessee, Illinois, California and Colorado.

The large percentage of flowers used in the United States is imported principally from Japan and to a lesser extent from Dalmatia. All other imports put together constitute but a small proportion of our commercial

Table 1.—Sources of imports of pyrethrum flowers into the United States.

	1932		1933		1934	
	POUNDS	DOLLARS	POUNDS	DOLLARS	POUNDS	DOLLARS
Japan	11,061,949	1,206,692	9,066,040	1,373,450	10,093,612	1,985,603
Yugoslavia	612,965	59,910	838,256	94,372	298,684	47,596
Italy	421,658	41,865	446,197	52,072	79,933	13,288
United Kingdom					42,369	6,340
U.S.S.R.	14,164	625	84,066	3,855	30,395	1,330
Brazil					4,480	1,086
Total	12,110,736	1,309,092	10,434,559	1,523,748	10,549,473	2,055,243

supply. The accompanying statistics from *World Trade Notes* of February 9, 1935, show the sources of imports into the United States during 1932, 1933 and 1934, together with the poundage and its value from each country of origin.

It will be observed from table 1 that pyrethrum imports into the United States during 1934 showed a gain over the previous year of 1 per cent in quantity and 35 per cent in value. Japanese participation rose from 90 to 95 per cent of the total. Brazil, a new producer, furnished a small quantity. Kenya Colony is also a comparatively new producer. Until recently, however, the bulk of the flowers grown there have been consumed locally and in Great Britain. France grows a considerable quantity of pyrethrum, but its production during recent years has gone mainly into domestic use.

The toxic principles of pyrethrum were established in 1916 by Staudinger & Ruzicka as cyclic esters of the ketonic alcohol pyrethrolone. These chemical compounds are commonly referred to as pyrethrin I and pyrethrin II. Of the principal sources of supply, the Japanese flowers have the greatest toxic content. The Dalmatian flowers contain on the average only about 50 per cent as much toxicity. The Kenya flowers have the greatest pyrethrin content of all, while the *roseum* flowers, grown mostly in Russia, assay on the average the lowest in pyrethrin

Table 2.—The toxic value of pyrethrum from various sources.

Source	Sample	Per Cent Pyrethrin I	Per Cent Pyrethrin II	Total Per Cent	Per Cent Down (10 Min.)	Per Cent Kill (24 Hrs.)
Japan	High	.54	.71	1.25	100	71
	Low	.34	.42	.76	94	57
	Average	.45	.55	1	98	66
Dalmatia	High	.47	.63	1.10	99	68
	Low	.18	.20	.38	86	37
	Average	.20	.29	.49	86	42
Kenya	Typical	.65	.71	1.36	100	83
U.S.A.	Typical	.22	.23	.45	87	40
France	Typical	.21	.24	.45	86	41
Brazil	Typical	.20	.25	.45	87	41
Bulgaria	Typical	.18	.21	.39	85	36
U.S.S.R. (*C. roseum*)	Typical	.10	.13	.23	81	30

content. The relative toxicity of the flowers grown in other places may be observed from table 2. This table shows the high, low and average pyrethrin content of considerable quantities of Japanese and Dalmatian flowers and the pyrethrin content of average samples of flowers from other sources. These data have been compiled from work done during the past six years in our laboratories. The figures covering the biological evaluations of toxicity, as expressed by percentage knockdown and kill, were obtained in our standard Peet-Grady test chamber. As is usual, 5-day-old house flies were used and the sprays were prepared by extracting the ground flowers with kerosene at the rate of 1 pound per gallon.

INSECTICIDAL ACTIVITY OF ALIPHATIC THIOCYANATES[1]

III. RED SPIDERS AND MITES

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In two previous papers Murphy & Peet (*1*, *2*) reported the results of laboratory and field tests to determine the effectiveness of certain aliphatic thiocyanates as contact insecticides for the control of aphis and

[1] The author has considered it preferable in this paper as well as in the prior ones to use the English term "thiocyanates" instead of the term "rhodanides or rhodanates" perferred in the German literature.

mealybugs. Since publication of those results other investigators have studied the value of thiocyanates as insecticides and have published some very interesting data. The work done by Wilcoxon & Hartzell (*6*, *7*) at the Boyce-Thompson Institute is particularly interesting since they report results on a number of different thiocyanates, some of which are of little value as insecticides while others appear to hold considerable promise. This general observation, that is, that the insecticidal activity of thiocyanates is tied up with constitutional differences of the compounds, has been noted by workers in the laboratories of the Rohm & Haas Company, Inc., where research on thiocyanates as insecticides has been going on for more than 10 years. In this work thousands of thiocyanates have been synthesized in our laboratories and tested as insecticides. The majority of these compounds have proven to be of no practical value but a few have definitely outstanding qualities as contact insecticides. One of these outstanding compounds is B butoxy B′ thiocyanodiethylether, which we have placed on the market in a suitable form under the trade names *Lethane 420* and *Lethane 440*. These products have met with wide acceptance in greenhouse, nursery and orchard work, particularly as controls for the more resistant insects such as mealybugs and other scales, red spiders, chrysanthemum midge, thrips, European red mite, wooly apple aphis, leafhoppers, etc. Our results, published and unpublished, on these products have been fully substantiated by workers in various experiment stations as well as other qualified institutions. Neiswander (*3*), Richardson (*4*), and Steiner (*5*), report the results of experiments on *Lethane 420* and other insecticides containing thiocyanates against such insects as mealybugs, apple leafhoppers, etc.

Methods.—This paper deals with certain laboratory and field tests on B butoxy B′ thiocyanodiethylether as a control for red spiders and mites, conducted 1932–35. The specific pests used in these tests were *Tetranychus telarius* L. and *Paratetranychus pilosus* C. & F. In the laboratory tests heavily infested plants were carefully and thoroughly sprayed by means of a small atomizer which delivered a fine mist at a fairly uniform pressure. After being sprayed, each plant was placed in the center of a white porcelain plate the periphery of which was covered with a thin band of tanglefoot diluted with castor oil. The thinned tanglefoot made a light-colored barrier in which any spiders caught were easily discernible and spiders found in this barrier were considered to be alive. Unlike the case with aphis, in these tests on red spiders very few of the pests left the plants and hence only rarely were any found in the tanglefoot. Twenty-four or 48 hours after spraying, as the case called for, the sprayed plants were cut to pieces and each leaf and branch was carefully examined under magnification and the total number of dead and live spiders or mites were accurately counted. From these figures, the percentage of pests killed by the insecticide was derived. Unsprayed plants were always kept in the laboratory during these tests and although no accurate counts were made of the number of spiders present, careful observations were made to make sure that these unsprayed spiders were alive and that no outside factors were influencing the tests.

Tests on greenhouse red spider, *Tetranychus telarius* L.—*Labo-*

ratory Tests.—Tests, as described above, were conducted on B butoxy B′ thiocyanodiethylether in comparison with commercial pyrethrum, derris and selenium insecticides. The red spiders used in these tests were on Jerusalem cherry and carnations. Twenty-four-hour counts were made in all of these experiments. In using the commercial insecticides the recommendations of the manufacturers for red spider control were rigidly followed. During the first part of this experimental work sodium

Table 1.—Summary of laboratory tests on *Tetranychus telarius* L. The host plant is Jerusalem cherry.

Insecticide	Dilution	Spreader Dilution	No. Tests	Average Per Cent Kill
B butoxy B′ thiocyanodiethylether	1:600	1:200	35	98
B butoxy B′ thiocyanodiethylether	1:800	1:200	60	95
B butoxy B′ thiocyanodiethylether	1:1000	1:200	25	76
Commercial pyrethrum spray	1:200		30	34
Commercial derris spray No. 1	1:200		30	61
Commercial derris spray No. 2	1:500		30	74
Commercial selenium spray	1:50		30	95

lauryl sulfate was used as a spreader. This was later discontinued in favor of a 10 per cent solution of sulfonated complex aromatic amines. The thiocyanate was emulsified with a sulfonated oil using 1 part by volume of the emulsifier with 2 parts of the thiocyanate. The spreader was used with this emulsion in the finished spray. The spreader and emulsifier without the thiocyanate had no effect on the spiders. Table 1 summarizes our laboratory tests on *Tetranychus telarius* L.

In the individual tests summarized in table 1 the red spiders varied in numbers from 74 to 194 with an average of 117. During the two-year period covering these tests a large number of laboratory tests not included in the table were carried on. The results are, however, thoroughly representative of all our laboratory work on red spiders.

Table 2.—Tests of Lethane 420 on *Tetranychus telarius*.

Host	Dilution	Spreader Dilution	No. Counts	No. Live Spiders Before Spraying	No. Live Spiders After Spraying
Matchless White Carnation	1:400	1:200	40	1836	92
Spectrum Carnation	1:400	1:200	30	746	67

It will be noted that at 1:600 and 1:800 the thiocyanate gives excellent kills but that when diluted to 1:1000 the kill drops significantly. None of the derris or pyrethrum sprays approached the thiocyanate in effectiveness but the selenium spray is about equal to it.

On the basis of these and many similar tests we definitely established that the lowest concentration at which the thiocyanate would give satisfactory control with economy was the 1:800 dilution. No ill effect on the host plant was noted.

Greenhouse Tests.—In the form of *Lethane 420* and *Lethane 440* B butoxy B′ thiocyanodiethylether has been thoroughly tested under practical conditions. The practical tests on red spiders were conducted

in the Philadelphia area. Table 2 shows results typical of those obtained.

These tests were conducted on benched carnations of two varieties, Matchless White and Spectrum. The spray was applied by means of a bucket sprayer at about 150 pounds pressure. Counts of the live spiders were made immediately before and 24 hours after spraying. In the case of the Matchless White variety, which was rather heavily infested, 40 leaves were picked at random and the number of spiders on these were counted, there being a total of 1836 live spiders. This procedure was repeated 24 hours after the application of the spray, at which time 92 live spiders were found. This represented a control of about 95 per cent. In the case of the Spectrum variety 30 leaves were counted before and a like number 24 hours after spraying. Seven hundred forty-six live spiders were counted before spraying and 67 after spraying, showing a control of about 90 per cent.

During this work we noted that the thiocyanate had a very definite ovicidal action. Preliminary tests and observations indicate that B butoxy B′ thiocyanodiethylether at 1:800 destroys about 70 per cent of red spider eggs. The ovicidal action of the organic thiocyanates is being investigated further and a report on this phase of the work will be made at a later date. In the greenhouse tests there was again observed to be no ill effect on the plants.

Tests on the European red mite, *Paratetranychus pilosus* C. & F.—Field tests on B butoxy B′ thiocyanodiethylether against the European red mite on apple trees were conducted during 1933 and 1934. These tests were carried out in orchards in eastern Pennsylvania and the thiocyanante was incorporated as a contact spray in the regular spray schedules. In most cases it was used in combination with lime sulfur or flotation sulfur since it was necessary to use a fungicide for apple scab when our sprays were applied.

The following combinations were tested:

1.—B butoxy B′ thiocyanodiethylether 1:800 plus spreader 1:300 plus lime sulfur summer strength, on Staymans and Rome Beauties.

2.—B butoxy B′ thiocyanodiethylether 1:1600 plus spreader 1:300 plus flotation sulfur 10 pounds per 100 gallons, on Rome Beauties.

3.—B butoxy B′ thiocyanodiethylether 1:2400 plus spreader 1:300 plus flotation sulfur 10 pounds per 100 gallons, on Rome Beauties.

4.—Lime sulfur at summer strength alone, on Rome Beauties.

5.—Flotation sulfur 10 pounds per 100 gallons, on Rome Beauties.

The sprays were applied by means of a power sprayer at 400–500 pounds pressure. The materials were put on in a very thorough manner from the inside as well as from the outside of the trees. The days on which applications were made were bright with a hot sun and the temperature ranged from 80 to 90° F.

Counts of the number of live mites on the sprayed and on unsprayed trees were made 24 hours after spraying on all the tests, 48 hours after on some and 13 days later on one.

The data were obtained by counting under magnification 15 leaves from each of several trees in each sprayed block as well as from five trees in the unsprayed block. The results are summarized in table 3.

In these tests the spreader used was the same as that employed in the laboratory tests against red spider. The thiocyanate was emulsified with the sulfonated oil, as for red spiders. Both the thiocyanante and spreader are entirely compatible with lime sulfur, flotation sulfur, lead arsenate and other spray materials.

It will be noted that there were an average of about 26 live mites on each leaf on the unsprayed trees. The flotation sulfur reduced the average very little, thus giving practically no control. The use of lime sulfur

Table 3.—Results of field tests of B butoxy B′ thiocyanodiethylether on *Paratetranychus pilosus*.

Dilution	Lime Sulfur	Flotation Sulfur	Spreader	No. Counts	Total No. Live Mites	Ave. No. Live Mites per Leaf	No. of Days Count Made After Spraying
1:800	Summer strength		1:300	75	58	.77	1
1:1600		10 lbs. per 100 gals.	1:300	75	157	2.1	
1:2400		10 lbs. per 100 gals.	1:300	75	172	2.3	1
	Summer Strength			30	423	14.1	1
		10 lbs. per 100 gals.		40	914	22.8	1
1:2400	Summer Strength		1:300	75	45	.6	2
1:2400	Summer Strength		1:300	60	510	8.5	13
Unsprayed Check Trees				60	1553	25.9	

alone reduced the average mite population from 26 to 14, thus giving a significant reduction but not enough to give practical control.

The thiocyanate 1:800 plus summer strength lime sulfur gave very good control, reducing average number of mites per leaf to .77. When used at 1:1600 and 1:2400 in combination with flotation sulfur 10 pounds per 100 gallons, the thiocyanate reduced the average population per leaf to about 2 mites. The thiocyanate 1:2400 plus summer strength lime sulfur gave very good control, reducing the average population to .6 mite per leaf. It should be noted that two weeks after the thiocyanate–lime sulfur combination had been applied, the mite population had built itself up to an average of about 8 mites per leaf.

Further applications of B butoxy B′ thiocyanodiethylether at 1:2400 plus lime sulfur and at 1:2400 alone have corroborated the above findings.

Conclusions.—Laboratory and field tests have demonstrated that B butoxy B′ thiocyanodiethylether at 1:800 when properly emulsified and used with a spreader successfully controls the greenhouse red spider, *Tetranychus telarius* L.

Tests conducted under field conditions on the European red mite, *Paratetranychus pilosus* C. & F., on apples indicate that B butoxy B′ thiocyanodiethylether at 1:2400 when properly emulsified and used

with a spreader gives good control. The thiocyanante may be used with lime sulfur or flotation sulfur to make a combination contact insecticide and fungicide.

Preliminary tests indicate that the thiocyanante at 1:800 will destroy about 70 per cent of the eggs of the red spider. Further work must be done on this phase of the problem.

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TESTS OF POSSIBLE SUBSTITUTES FOR HYDROCYANIC ACID IN FUMIGATION OF CALIFORNIA RED SCALE

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This paper describes toxicity tests on the California red scale, *Chrysomphalus aurantii* Maskell, with more than 300 chemical compounds, made in the effort to find fumigants better than, or capable of improving the action of, hydrocyanic acid. It seems desirable to record the results for the guidance of future investigators, even though the results to date (Dec. 1934) have not led to definitely favorable developments.

Apparatus and methods of procedure.—In general each compound has been given two trials, and these have excluded most of the compounds from further consideration. However, as may be seen from subsequent sections of this report, these series of tests have not been entirely completed. In the first trial, infested lemons were exposed to the highest obtainable concentration of the compound, at room temperature, usually for a period of 25 minutes. This was done by suspending the lemons in a covered desiccator provided with an electrically driven fan, and placing the compound in a shallow open dish on the bottom of the desiccator. Thus the lemons were exposed to air which was substantially saturated with the compound under test, at room temperature. If some of the scales survived this treatment, the compound was not further

considered, except as an auxiliary gas with hydrocyanic acid. However, if this experiment resulted in a complete kill of the scales, then further experiments were made to determine whether a proper dosage of the fumigant would kill the scales without injuring the lemons. If so, the investigation of the compound was carried still further.

The second of the two trials involved the use of the compound as an auxiliary gas with hydrocyanic acid. The apparatus used for these experiments was essentially that described in a previous publication[1] with such additions as were required for the introduction of the auxiliary gases. The auxiliary compound was in most cases a liquid, the vapor of which was introduced by passing a measured current of air through the liquid contained in a small flask, which was weighed before and after the experiment. In these tests the usual procedure was to expose the infested lemons for 25 minutes, at 25° C (77° F) to air containing 1.5 mg. per liter of hydrocyanic acid plus the auxiliary gas. The effectiveness of the auxiliary gas was judged by comparing the scale mortality thus obtained with that of a control experiment in which no auxiliary gas was added. In testing the various compounds as auxiliary gases, although an effort was made to introduce them at a concentration of 10 mg. per liter, the hydrocyanic acid concentration being kept constant at 1.5 mg. per liter, the actual concentrations varied quite widely. Obviously, many of the high-boiling compounds could be tested only at lower concentrations. It may be mentioned at this point that the tests included many compounds which seem to be immediately excluded as practical fumigants; they have been included in order to add to the thoroughness and completeness of the investigation, and because there seems to be no known method of foretelling the activating effect of an auxiliary gas.

As the vitality of the scale varies with the climatic conditions, host material, and density of population, it is necessary to choose the scales for these experiments with care and it is likewise necessary to make comparisons only between experiments which are truly comparable. Lemons which were heavily infested, but not overcrowded, with the California red scale were selected from infested groves. Green lemons of almost mature size were preferable, and were usually obtained. The infested material was brought into the laboratory fresh from the field, and the exposures were made not later than one or two days after the fruits were cut from the trees. With careful handling the host material showed no signs of deterioration. The treated material was placed in a darkened room, cooled to a mean temperature not exceeding 18° C (64.4° F), to retard the growth of the surviving scales. The mortality counts were made from five to 10 days after treatment, using a binocular microscope magnifying about 20 diameters with artificial light. Dead scales were distinguished from the living by changes in color and conformation of the insect body.[2] Unless otherwise stated, the toxicity of a chemical was determined by the percentage of the surviving female scales in the second-molt and early-gray stages.

[1] **H. L. Cupples.** 1933. Indus. Eng. Chem., Anal. Ed., 5:36.
[2] **Stickney, F. S.** and H. R. Yust. 1933. Jour. Ag. Res. 46:137–47.

Tabulation of experiments.—In the following lists each compound has been allocated to one of three groups, depending upon its indicated toxicity to the red scale. When a compound is used as a practical fumigant, its effect on citrus vegetation is as important as its toxicity to the scales, but in this tabulation the compound has been rated solely on the basis of toxicity to the scale. A considerable number of the compounds, however, burn the lemons very badly and thus make it difficult to determine their toxicity to the scale.

Group I lists in alphabetical order those compounds which have shown little or no toxicity to the red scale. Group II includes those compounds which are only moderately toxic, or for which the results are somewhat inconclusive because of bad burning of the fruit. Group III includes the relatively few compounds which have shown a substantial degree of toxicity. Following the name of each compound will be found the designation (A), (B) or (C): compounds which have been tested alone are designated (A), those tested in conjunction with hydrocyanic acid are designated (B), and those tested in both ways are designated (C).

GROUP I

COMPOUNDS SHOWING SLIGHT OR NO TOXICITY.—Acetal (C), acetaldehyde[3] (C), acetamide (A), acetic acid (C), acetodichlorohydrin (C), acetone (B), acetonitrile (C), acetyl bromide (B), acetyl n-butylaniline (C), acetyl chloride[4] (A), acetyldiethylamine (C), acetylene[5] (A), acetyl piperidine (C), adipyl chloride (C), allyl alcohol (B), allylamine (B), allyl bromide (B), allyl chloride (B), allyl cyanide (C), allyl ethyl ether (B), allyl formate (B), allyl iodide (B), allyl sulfide (C), 2-amino p-cymene (C), p-aminodiethylaniline (C), 2-amino 1–3-dimethylbenzene (C), 2-amino 1–4-dimethylbenzene (C), 4-amino 1–3-dimethylbenzene (C), 5-amino 1–3-dimethylbenzene (C), beta amino-n-octane (C), ammonia (B), n-amyl acetate (C), isoamyl acetate (C), n-amyl alcohol (C), isoamyl alcohol (C), sec amyl alcohol (C), tert amyl alcohol (C), n-amylamine (C), isoamylamine (B), isoamylaniline (C), tert amylbenzene (C), isoamyl benzoate (C), n-amyl bromide (C), isoamyl bromide (C), n-amyl n-butyrate (C), isoamyl butyrate (C), isoamyl n-caproate (C), isoamyl n-caprylate (C), isoamyl carbonate (C), n-amyl chloride (B), isoamyl chloride (B), isoamyl chlorocarbonate (C), alpha n-amylcinnamaldehyde (C), n-amyl disulfide (C), amylene[6] (C), isoamyl mercaptan (B), isoamyl nitrite (B), anethole (C), aniline (C), anisaldehyde (C), o-anisidine (C), m-anisidine (C), anisole (C), anthracene (A), benzal chloride (C), benzaldehyde (C), benzalmethylamine (C), benzene (B), benzonitrile (C), benzotrichloride (C), benzoyl bromide (C), benzyl acetate (C), benzyl alcohol (C), benzylamine (C), benzyl bromide (C), benzyl butyrate (C), benzyl chloride (C), benzyl chloroacetate (C), benzyl ether (C), o-bromobenzyl chloride (C), alpha bromo n-butyric acid (C), alpha bromo n-caproic acid (C), bromocyclohexane (C), 2-bromocymene (C), o-bromodiphenyl (C), p-bromodiphenyl ether (C),

[3] Dosage without HCN about 2 mg. per liter.
[4] Dosage 9.3 mg. per liter.
[5] Dosage 10 per cent by volume of a mixture of PH_3 and C_2H_2, roughly 1:1.
[6] Dosage without HCN 6.9 mg. per liter.

beta bromoethyl acetate (C), alpha bromoethylbenzene (C), beta bromoethyl ethyl ether (B), 2-bromo octane (C), alpha bromopropionic acid (C), beta bromo n-propyl acetate (B), gamma bromopropyl acetate (C), 3-bromopyridine (C), o-bromotoluene (C), m-bromotoluene (C), alpha bromo n-valeric acid (C), secbutyl alcohol (B), n-butylamine (B), isobutylamine (B), secbutylamine (B), n-butyl benzoate (C), isobutyl benzoate (C), n-butyl benzyl ether (C), n-butyl bromide (B), isobutyl bromide (B), secbutyl bromide (B), tertbutyl bromide (B), n-butyl n-butyrate (C), isobutyl n-butyrate (C), isobutyl isobutyrate (C), n-butyl n-caproate (C), isobutyl n-caproate (C), secbutylcarbinol (C), n-butyl carbonate (C), n-butyl chloride (B), isobutyl chloride (B), secbutyl chloride (B), tertbutyl chloride (B), n-butyl formate (B), n-butyl mercaptan (B), n-butyl nitrite (B), isobutyl propionate (C), n-butyl sulfide (C), isobutyl sulfide (C), n-butyl d-tartrate (C), n-butyl p-toluenesulfonate (C), n-butyl n-valerate (C), n-butyraldehyde (B), isobutyraldehyde (B), n-butyryl chloride (B), carbon monoxide[7] (C), carbon tetrachloride (B), chloral (B), chloroform (B), chloromethyl ether (B), citronella oil (A), clove oil (A), pseudocumene (B), cyclohexane (C), diacetyl (B), alpha beta dibromoethylene (B), di-isobutylene (B), p-dichlorobenzene (A), s-dichloroethylene (B), s-dichloromethyl ether (B), diethylamine (B), diethyl ketone (B), dimethyl acetal (B), 2–4-dimethylpentanol-3 (C), 1–4-dioxane (B), di-n-propylamine (B), di-isopropylamine (C), epichlorohydrin (B), ether (B), ethyl acetate (C), ethylal (B), ethyl alcohol (B), ethyl bromide (B), ethyl-n-butyl ether (B), ethyl n-butyrate (B), ethyl isobutyrate (B), ethyl carbonate (B), ethyl chlorocarbonate (B), ethylene chloride (B), ethylene chlorohydrin (B), ethylene glycol diformate (B), ethyl formate (B), ethylidene bromide (B), ethylidene chloride (B), ethyl iodide (B), ethyl mercaptan (B), ethyl nitrate (B), ethyl propionate (B), 1-ethylpyrrole (C), ethyl sulfide (C), ethyl thioacetate (B), eucalyptus oil (A), p-fluoroaniline (C), p-fluoroanisole (C), fluorobenzene (B), p-fluorobromobenzene (C), o-fluorochlorobenzene (C), m-fluorotoluene (C), p-fluorotoluene (C), formaldehyde (B), furane (B), furonitrile (C), guaiacol n-caproate (C), n-heptylamine (C), hydrogen chloride (B), beta hydroxyethylformate (B), iron carbonyl[8] (A), menthol (A), methoxymethylal (B), methyl alcohol (B), methyl n-amyl ether (B), methyl bromide (B), methyl bromoacetate (C), methyl n-butyl ether (B), methyl n-butyl ketone (B), methyl isobutyl ketone (B), methyl carbonate (B), o-methylcyclohexanone (C), m-methylcyclohexanone (C), p-methylcyclohexanone (C), 3-methylcyclohexene (C), methyl disulfide[9] (C), methylene bromide (B), methylene iodide (B), methyl ethyl ketone (C), methyl formate (C), methyl iodide (B), methyl isopropyl carbinol (B), methyl n-propyl ketone[10] (C), methyl isopropyl ketone (C), l-methylpyrrole (B), methyl salicylate (A), naphthalene (A), naphthol (A), nicotine (C), nitrobenzene (A), nitromethane (C), nitrous oxide[11] (B), n-octane (C), oxygen[12] (B), n-

[7] Dosage 3 per cent by volume with and without HCN.
[8] Present as 1:1 solution in kerosene.
[9] Dosage without HCN 9.4 mg. per liter.
[10] Dosage without HCN 9.4 mg. per liter.
[11] Dosage 2 per cent by volume.
[12] Tests made with air–oxygen mixtures containing 17 and 48 per cent, respectively, of added oxygen.

pentane (C), isopentane (C), phenol (A), phosphine[5] (A), alpha picoline[13] (C), pinacolone (C), pinene (C), propionaldehyde[14] (C), propionic acid (C), propionitrile (B), propionyl chloride (B), n-propyl acetate (B), isopropyl acetate (B), n-propylal (C), n-propyl alcohol (B), n-propylamine (B), isopropylamine (B), n-propyl bromide (B), isopropyl bromide (B), n-propyl chloride (C), isopropyl chloride (C), propylene bromide (C), propylene bromohydrine (B), propylene chloride (C), propylene oxide (B), n-propyl formate (B), isopropyl formate (B), n-propyl iodide (B), isopropyl iodide (C), n-propyl mercaptan (B), isopropyl mercaptan (B), n-propyl sulfide (C), pyridine (C), salicylaldehyde (C), s-tetrachloroethane (C), tetrachloroethylene (A), thioacetic acid (B), o-thiocresol (B), thiocyanic acid[15] (A), thionyl chloride (B), thiophene (B), thiophenol (C), beta beta beta trichloro-tertbutyl acetate (C), triethylamine (B), trimethylene chlorobromide (C), trimethylethylene (B), 2–2–4-trimethylpentane (B), n-valeraldehyde (B), isovaleraldehyde (B), vinyl chloride[16] (B).

GROUP II

MODERATELY TOXIC.—Acetylacetone (C), acrolein (B), allyl isothiocyanate (C), arsenic trichloride (B), bromoform (C), bromopicrin (C), carbon disulfide (C), carbon dioxide[17] (C), crotonaldehyde (B), ethyl bromoacetate (C), ethyl nitrite (C), o-fluorotoluene (C), formic acid (B), gasoline (C), methylamine[18] (C), methyl chlorocarbonate[19] (C), methylene chloride (C), alpha methylhydroxylamine (A), methyl nitrite[20] (C), methyl selenocyanate (C), methyl sulfide (A), perchloromethyl mercaptan (C), piperidine (C), n-propyl ether (C), n-propyl n-propionate (C), sulfur dioxide[21] (A), trichloroethylene (C), vinyl acetate (C).

GROUP III

DECIDEDLY TOXIC.—In considering the various experiments listed in this group, it may be noted that a dosage of 1.5 mg. hydrocyanic acid per liter, for 25 minutes, at 25° C (77° F), ordinarily gave a survival of 15 to 30 per cent, with occasional large deviations. In the toxicity tests described below, the scale survival, unless otherwise noted, refers to the resistant stages only.

Isobutyl mercaptan—Mol. wt. 90.1; B.P. 87–89° C (188.6–192.2° F). Scale exposed to a saturated atmosphere for 25 minutes at room temperature slowed a survival of 3.2 per cent. In another test 2 cc. of the compound were vaporized into a 50-gallon barrel containing infested lemons; the lemons were removed after 25 minutes, the scale showing a survival of 89 per cent.

[13] Dosage without HCN 42 mg per liter.
[14] Dosage without HCN 11.4 mg. per liter, plus 5 per cent CO_2.
[15] Dosage without HCN 1.8 and 3 mg. per liter.
[16] Dosage 2 per cent by volume.
[17] Carbon dioxide has been tested in conjunction with acetaldehyde, chloropicrin, ethylene oxide, methyl disulfide, methyl thiocyanate, propionaldehyde, and sulfur dioxide in addition to hydrocyanic acid. In an extensive series of tests with HCN it was found that the addition of 10 per cent of CO_2, by volume, reduced the number of surviving scales by about 30 per cent. In no case, however, did it appear effective enough to warrant practical use.
[18] Dosage without HCN about 8 mg. per liter.
[19] Dosage without HCN 12.9 mg. per liter.
[20] Dosage 2 per cent by volume with and without HCN.
[21] Dosage .75 to 3 g. of sulfur burned beneath a 50-gallon barrel.

n-Butyl thiocyanate—Mol. wt. 115.1; B.P. 180–183° C (356–359.6° F). In one test a concentration of 3.8 mg. per liter in conjunction with 1.5 mg. per liter of hydrocyanic acid for 25 minutes at 25° C gave a scale survival of 2.7 per cent. Scale exposed to a saturated atmosphere for 25 minutes at 25° C showed a survival of 71 per cent.

Chloropicrin—Mol. wt. 164.4; B.P. 110–111° C (230–231.8° F). A dosage of 8.8 mg. per liter in conjunction with 1.5 mg. per liter of hydrocyanic acid, for 25 minutes at 25° C, gave a scale survival of 30 per cent. A dosage of 10 mg. per liter for 25 minutes at 25° C, with no hydrocyanic acid, gave a survival of 25 per cent, with injury to the lemons. A dosage of 9.5 mg. per liter for 25 minutes at 25° C, together with 5 per cent by volume of CO_2, gave a scale survival of 8 per cent, with injury to the lemons.

Ethyl acrylate—Mol. wt. 100.1; B.P. 98–102° C (208.4–215.6° F). Exposure to saturated atmosphere for 25 minutes at room temperature gave a scale survival of 5 per cent. A dosage of 10 mg. per liter for 30 minutes at 25° C, with 1.5 mg. per liter of hydrocyanic acid added during the last 25 minutes, gave a survival of 3 per cent.

Ethylene oxide[22]—Mol. wt. 44; B.P. 14° C (57.2° F). A dosage of .8 per cent by volume for 35 minutes at 25° C, with .9 mg. per liter of hydrocyanic acid during the last 30 minutes, gave a scale survival of 16 per cent. A series of tests indicated that a dosage of 2.4 per cent by volume of ethylene oxide for 45 minutes at 25° C would kill 100 per cent of the scale.

Ethyl thiocyanate—Mol. wt. 87.1; B.P. 146–147° C (294.8–296.6° F). A dosage of 3.5 mg. per liter for 25 minutes at 25° C gave a scale survival (all stages) of 38 per cent. A dosage of 4.8 mg. per liter for 25 minutes at 25° C killed the scale. Additional experiments with this compound would seem to be desirable.

Ethyl isothiocyanate—Mol. wt. 87.1; B.P. 129–131° C. (264.2–267.8° F) A dosage of 6.6 mg. per liter, together with 1.5 mg. per liter of hydrocyanic acid, for 25 minutes at 25° C, gave a survival of 3 per cent. In another test a dosage of 7.6 mg. per liter, together with 1.5 mg. per liter of hydrocyanic acid, for 25 minutes at 25° C, gave a survival of 21 per cent. These results indicate the occasional great variability in results, which we were unable to avoid.

Hydrogen sulfide—Mol. wt. 34.1; B.P. −60° C (−76° F). A dosage of 25 per cent by volume for 25 minutes at room temperature gave a scale survival of 1 per cent.

Methyl acetate—Mol. wt. 74.1; B.P. 56.5–57° C (133.5–134.6° F). Exposure to a saturated atmosphere for 45 minutes at 25° C showed a survival of 2 per cent, with severe burning of the lemons. A dosage of 14 mg. per liter, together with 1.5 mg. per liter of hydrocyanic acid, for 25 minutes at 25° C, gave a scale survival of 23 per cent.

Methyl propionate—Mol. wt. 88.1; B.P. 78–81° C (172.4–177.8° F). Exposure to a saturated atmosphere for 25 minutes at room temperature gave a scale survival of .2 per cent. A 25-minute dosage with 4 cc. of the liquid atomized into a 50-gallon barrel gave a survival of 93 per cent. A

[22] Also tested in conjunction with CO_2.

dosage of 11 mg. per liter for 30 minutes at 25° C, with 1.5 mg. per liter of hydrocyanic acid during the last 25 minutes, gave a scale survival of 1.8 per cent.

Methyl thiocyanate—Mol. wt. 73.1; B.P. 133° C (271.4° F). In one test a dosage of 6.6 mg. per liter for 30 minutes at 25° C, with 1.5 mg. per liter of hydrocyanic acid during the last 25 minutes, gave a scale survival of .9 per cent. A dosage of 10 mg. per liter for 25 minutes at 25° C gave a scale survival (all stages) of .3 per cent.

Methyl isothiocyanate—Mol. wt. 73.1; B.P. 119° C (246.2° F). A dosage of 7.4 mg. per liter of 1:1 mixture with methyl thiocyanate for 25 minutes at 25° C gave a scale survival (all stages) of .8 per cent.

Oxalyl chloride—Mol. wt. 126.9; B.P. 64° C (147.2° F). A 25-minute dosage with 3 cc. of the liquid sprayed into a 50-gallon barrel gave a scale survival of 19 per cent.

n-Propyl chlorocarbonate—Mol. wt. 122.5; B.P. 113–115° C (235.4–239° F). Exposure to a saturated atmosphere for 25 minutes at room temperature gave a scale survival of 11 per cent. A dosage of 12.2 mg. per liter for 25 minutes at 25° C gave a survival of 78 per cent.

Isopropyl ether—Mol. wt. 102.1; B.P. 67–69° C (152.6–156.2° F). Exposure to a saturated atmosphere for 25 minutes at room temperature gave a scale survival of 21 per cent.

Isopropyl thiocyanate.—Mol. wt. 101.1; B.P. 146–151° C (294.8–303.8° F). In one experiment a dosage of 6.3 mg. per liter for 25 minutes at 25° C gave a scale survival (all stages) of 40 per cent.

Summary and discussion.—Comparatively few of the compounds tested showed a substantial toxic action to the California red scale, and no compound which was not toxic to the scale was found to be markedly effective with hydrocyanic acid. Ethylene oxide is moderately toxic, but concentrations sufficient to kill the scale will injure the foliage. Chloropicrin is toxic to the scale, but also readily burns the fruit. Practically a complete kill of scale was obtained with hydrogen sulfide at a dosage of 25 per cent by volume for 25 minutes, but, although we have made no tests on foliage with this compound, it is believed that such a dosage would severely injure citrus vegetation. In fact, similar statements might be made with respect to many of the compounds included in Groups II and III. The results emphasize the severity of the requirements.

Pratt, Swain & Eldred,[23] using ladybird beetles to determine toxicity, found that the addition of carbon dioxide decreased the toxicity of hydrocyanic acid to the test insects, whereas our work has shown that a 10 per cent concentration of carbon dioxide increases its toxicity to the red scale. Also, these authors have listed the following seven compounds as the best auxiliary gases, in their order of excellence: Salicylaldehyde, benzaldehyde, ethyl thiocyanate, allyl isothiocyanate, thiophenol, benzyl bromide, and perchloromethyl mercaptan. On the basis of our tests with the red scale, however, we have placed four of these compounds in Group I, two in Group II, and the remaining one in Group III. Salicylaldehyde and benzaldehyde, the two most effective auxiliary gases in their tests with ladybird beetles, we have placed in Group I. It is strongly indicated,

[23] 1933. Jour. Econ. Ent. 26(6):1031–41. Dec.

therefore, that tests with ladybird beetles cannot safely be interpreted in terms of the red scale.

We have found that various thiocyanates and isothiocyanates are toxic to the red scale at moderate concentrations, and of these two classes of compounds the former has seemed superior because less injurious to citrus fruit and foliage. Both methyl and ethyl thiocyanates have shown a high toxicity to the scale, with the methyl compound having the advantage of a lower boiling point. Methyl thiocyanate and hydrocyanic acid appear about equally effective in killing the red scale, molecule for molecule, methyl thiocyanate having the superior efficiency in obtaining a complete kill. Because of its lower molecular weight, however, hydrocyanic acid is superior on a weight basis. In some tests on citrus nursery stock, methyl thiocyanate proved inferior to hydrocyanic acid because of greater injury to the foliage.

In regard to the variation of toxicity with chemical structure, it may be mentioned that in the case of the thiocyanates there was no evidence that the toxicity increased with the molecular weight, or boiling point; in fact, the lower members of the series seemed to be the more effective. It is also of considerable interest to compare the toxicities to the red scale of the following three types of compounds:

(1) Hydrogen cyanide	H-CN	Very toxic.
(2) Organic cyanides (nitriles)	R-CN	Very slightly toxic.
(3) Organic thiocyanates	R-SCN	Very toxic.

Starting with HCN, a very toxic compound, the substitution of an organic radical (R) for the H atom produces a substantially nontoxic compound. However, if an atom of S is then introduced into the nitrile, R-CN, forming the thiocyanate, R-SCN, a very toxic compound is again obtained.

POSSIBLE INSECT CARRIERS IN THE 1933 OUTBREAK OF ENCEPHALITIS IN COLUMBIA, MO.[1]

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The outbreak of encephalitis at Columbia, Mo., in 1933, followed the much heavier epidemic in St. Louis and vicinity and it is believed that some of the cases, especially among university students, were contracted at St. Louis and showed up later after the patients came to Columbia. Indications are that two fraternity houses were rather definite centers or foci from which a number of the cases among university students radiated. Out of the 25 to 30 cases definitely diagnosed as encephalitis only one death occurred. Some of the other cases, however, were very severe, while the majority of them were light, and probably many cases

[1] Contribution from the Department of Entomology, Missouri Agricultural Experiment Station. Journal series paper 472.

occurred but were not diagnosed as such. Most of the cases were among the students in the University of Missouri, one of which proved fatal. Only a few cases occurred among the faculty and university employees and a small number occurred among business men and town people. Except for two or three cases which occurred in the country or neighboring towns, all the cases here referred to occurred in the city of Columbia and most of these were in the southwest part of it.

Cause of encephalitis.—In a discussion of a new or unusual disease like encephalitis naturally the first question that comes up is what is the disease, what causes it, and how is it spread. The writer's interest in the local epidemic was aroused by the possibility that it might be insect borne, the medical phases of the problem being entirely beyond his field of study. As pointed out in recent publications by medical investigators, it is now quite generally agreed that encephalitis is a virus disease closely akin in many respects to infantile paralysis. More recently they have also pointed out the possibility of a close relationship between influenza and encephalitis. Influenza is now also known to be a virus rather than a bacterial disease. Encephalitis first appeared following the 1918 "flu" epidemic. It very often follows an attack of "flu" and it is thought by some that encephalitis may be a form of "flu" which attacks the brain and nervous system.

Symptoms.—Similar to other diseases, the symptoms of encephalitis may vary in different patients but usually begin with stiff, aching joints as with "flu", stiff neck, severe headaches, which increase with pressure on the spinal fluid. The temperature usually rises rapidly and to an alarming height in the severe cases. Digestive disturbance was reported for most of the cases in St. Louis but at Columbia physicians report such disturbance as apparently due to high temperature. After the temperature breaks the patient usually sleeps most of the time for several days. Definite diagnosis of cases are made by examination of spinal fluid.

How encephalitis probably spreads.—The great abundance of mosquitoes associated with the outbreak of encephalitis in the St. Louis area and, later, also here at Columbia, led investigators to suspect that mosquitoes might play a part in the spread of the disease. However, in the experiments on convicts in Mississippi and Virginia, where mosquitoes were permitted to bite patients affected with encephalitis and then later bite healthy people, negative results were secured. However, as Dr. J. P. Leake of the U. S. Public Health Service pointed out during his visit to check up on the epidemic at Columbia, negative results in a case like this are not positive proof that such transmission is impossible. Then too, there are other blood-sucking insects, as will be pointed out later in this paper, which should be carefully checked. From experiments and observations to date, it seems to be the opinion of the medical profession that the disease is probably contracted through the nostrils and not from the bite of either blood-sucking insects or on food through the digestive tract. Intra-cerebral injections in monkeys of materials from the brain of victims of encephalitis gave positive symptoms in from eight to 14 days after injection. The same was true also of experiments with mice. In nature such introduction of the virus would be impossible. How-

ever, when the mouse brain virus was introduced in the nasal passages of healthy mice disease developed in practically all cases. In nature such introduction of the virus would be possible, providing the patient has close contact with someone or something carrying the virus. Just how sporadic outbreaks of the so-called virus diseases get started is still quite often a mystery to the medical profession.

In spite of the fact that most of the cases showed digestive disorder in the early stages of the disease, Dr. Leake and others investigating encephalitis seem to be of the opinion that the disease is not carried on foods. Many of the more important foods have been rather definitely eliminated as possible carriers by careful investigation. Here again, however, the fact that certain foods have been eliminated as possible sources of the trouble does not mean that foods should be entirely ignored in future investigations. The mere fact that the disease appeared in epidemic proportions during the period of heavy insect activity and practically disappeared with the fall rains and abatement of insect activity, is worth considering. Some of the virus diseases, so considered, run their course during the winter and the fact that the epidemic of encephalitis practically cleared up with the approach of winter might indicate that contact or mere exposure to this disease is not sufficient to keep the epidemic going. Also, the fact that other exposed members of families have not readily taken it and that few or no nurses and physicians have taken it while attending diseased patients would indicate that, unlike some of the virus diseases, it is not readily taken either by contact or exposure. It would therefore seem highly desirable that, until the causative agent is better understood and more definite knowledge regarding its spread is available, insects should not be ignored in the study of this disease.

Columbia cases in limited area.—All of the first six people who had encephalitis in Columbia were permanent residents and were not known to have been exposed to the disease by traveling where epidemics previously occurred. Five of the six cases were within a few blocks of each other and they all came down with the disease within a comparatively few days of each other. In no case did other members of their families take the disease. The later cases were practically all among the university students. In two fraternities and one rooming house more than one case occurred, though most of the cases among the university students were individual isolated cases but closely centered around the campus. In no case apparently did any instructor contract the disease from exposure in the classroom. The disease, like infantile paralysis, would appear to be much less readily taken than many communicable diseases.

Does sewage disposal play any part?—In connection with the St. Louis epidemic it was observed that in those areas where sewage disposal was less satisfactorily handled encephalitis was most prevalent. In the Columbia epidemic all, or practically all, of the reported cases occurred in the south and southwest portions of the city. Most of the first cases were within a one-half mile radius of the city's principal sewage disposal plant and the city dumping grounds, and practically all the cases were within a mile of them. The prevailing summer and fall winds are from the southwest. It is impossible to say, from present knowledge,

whether there is any connection between encephalitis and sewage disposal, but its tendency to prevail in areas adjacent to sewage disposal should be carefully considered. It is believed by some that sewage would serve as a favorable medium for viruses. Should there be any relation between sewage and encephalitis there would still be the question as to whether it might be spread by insects serving as common carriers or by wind.

Insects unusually abundant during the epidemic.—Besides mosquitoes, two other groups of insects, the leafhoppers and blowflies, were present in unprecedented numbers during the early part of the epidemic of encephalitis in Columbia. About the middle of September, associated with tornadolike weather, immense swarms of several species of leafhoppers came into towns and cities at night, often in numbers sufficient to darken the lights. They were apparently blown in from the country, for in the swarms, along with the leafhoppers, were stable flies, lacewings, tarnished plant bugs, and parasitic hymenoptera. It is a well-known fact that certain of the leafhoppers are responsible for the spread of important virus or mosaic diseases of plants. Some of the smaller species of leaf hoppers are also, at times, quite annoying by sucking blood from man. This is especially true when they come to lights at night. In other words, this family of notorious mosaic disease spreaders also includes some which, when opportunity offers, may suck blood from man and in the search for possible carriers of encephalitis should be considered. If, as has been proven, they are the natural reservoirs and spreaders of virus diseases of plants, they might well be looked upon with suspicion as possible distributors of viruses affecting man.

If, as has been previously pointed out, there are grounds for considering encephalitis as being associated with sewage disposal, the blowflies might very properly be given serious consideration. They are usually associated with garbage, sewage and other decaying materials, as well as with fresh fruits and other human foods. As direct carriers they might well be looked upon with suspicion. They were present in immense numbers at Columbia during the fall. The three most abundant species as determined by Dr. J. M. Aldrich were *Cynomyia cadavernina* R. D., *Calliphora erythrocephala* Mg., and *Phormia regina* Mg.

Summary.—The epidemic of encephalitis in Columbia, Missouri, began with some six cases, all permanent residents. Apparently none of these contracted the disease outside Columbia.

All cases of encephalitis were in a rather restricted section in the south and southwest parts of the city and within a radius of from one-fourth mile to approximately one mile from the city's principal sewage disposal plant and the regular dump, and most of them were in line with the usual prevailing winds from the disposal plant.

While there were a considerable number of cases the disease did not seem to be readily communicable by exposure or close association either before or after going to the hospital.

The three groups of insects which were outstanding at the beginning of or throughout the epidemic were the mosquitoes, leafhoppers and the large bluebottles or blowflies.

INSECT DAMAGE TO SEEDS OF *CRACCA VIRGINIANA* L.

JETHRO S. YIP, *U.S.D.A., Bureau of Plant Industry*[1]

While connected temporarily with the Division of Drug and Related Plants of the Bureau of Plant Industry, U.S.D.A., investigating plants containing insecticidal substances, the writer observed insect damage done to the seed of the native wild *Cracca virginiana* L., widely known as devils-shoestring and rabbit bean, but also referred to by a number of other common names. As this is one of the plants possessing possibilities as an insecticide, it appeared to be another instance of plants containing insecticidal substances being themselves subject to insect damage. Review of the literature revealed no detailed accounts of insect injuries to the seed of this plant, but this may perhaps be explained by the fact that the plant is a rather common weed in many sections and until recent years has not been credited with economic importance or possibilities.

Little's work[2] in 1931 showed that the roots of this plant possess promising insecticidal properties, although subsequent developments have demonstrated that this is true only in the case of plants from certain localities and under certain conditions which are not yet understood. His work, however, led to the discovery by Clark[3] that the roots of the plant contain rotenone and related substances in small and greatly varying quantities. These researches led to the investigation now under way in the Division already mentioned to determine the commercial possibilities of the plant in the wild state and its adaptiveness to cultivation. As its propagation is easily accomplished by seed and its commercial culture by that method suggested, the question of seed production is naturally important. The destruction of the seed by insects, if this occurs generally and from year to year, could be a serious handicap to growers. This fact prompted the writer to make a preliminary examination of the insects infesting the seed pods of this plant in a number of localities and to determine the damage done by them.

Description of the plant.—*Cracca virginiana* L. is a native North American perennial weed belonging to the bean family (Leguminoseae) and occurring from Canada to Florida, Texas and Mexico. It is quite abundant in some localities in the south and southeast and parts of Texas, but relatively rare in the northern limits of its range. It is found on both clay and sandy soils but prefers the dry sandy areas where other vegetation is comparatively sparse. Favorite locations are sandy knolls, where it occurs in the open, or among scattered pines and scrub oaks, and on railroad and highway embankments, where there is little competition with other and more vigorous vegetation.

[1] The writer gratefully acknowledges the valuable assistance and criticism of A. F. Sievers, senior biochemist of the Division of Drug and Related Plants, Bureau of Plant Industry, U.S.D.A., and J. C. Bridwell, a private specialist in Bruchidae, working in the U. S. National Museum, in connection with this investigation and the preparation of the manuscript; also the services of the taxonomists of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, U.S.D.A., who made the identifications as indicated in the text.

[2] 1931. JOUR. ECON. ENT. **24**(3):743–54. June.

[3] 1933. Science, **77**(1995):311–12. March 24.

The plant is 1–2 feet tall and consists of many individual stalks arising from a single crown. The leaf has 11 to 29 elliptic leaflets differing in some respects according to locality. Blooming occurs early in the season, the flowers resembling those of the sweet pea, colored with shades of cream, pink and purple. The seed is produced in narrow dehiscent pods, fig. 1, measuring not over 2 inches in length, which open gradually when they are mature, thus scattering the seed. The pods of any individual plant do not develop and mature uniformly, and inasmuch as the

Fig. 1.—Seed pods of *Cracca virginiana* L. Left, normal seed pods, slightly less than half life size. Right, seed pods, about 1½ times life size, showing (A) slightly opened pod; (B) pod opened to show presence of *Apion segnipes* Say and evidences of damage done; (C) single valve showing condition of contents and presence of larva of *Ulophora tephrosiella* Dyar.

mature pods shed their seed the collection of large quantities of the seed is likely to be difficult.

Collection of seed pods.—Closed ripe pods were collected by the writer and others at the following places: Ingram, Keysville, Kenbridge, Buckingham and Pendleton, Va., Largo[4] and Beltsville, Md., Hearne[5] and Sandflat,[5,6] Tex. The pods of each lot were kept in cloth bags until examined in the laboratory.

It was observed that in some localities the plants produced no pods at all, although in such cases the presence of a flower stalk clearly indicated

[4] Collected by J. W. Kelly.
[5] Collected by G. A. Russell and V. A. Little.
[6] Local designation of an area near Tyler, Tex., where *Cracca virginiana* occurs in abundance.

Table 1.—Condition of seed and insects found in seed pods of *Cracca virginiana* L.

Locality, Date Collected, Date Examined	No. Pods Examined	No. Seeds, Including Indications*	Per Cent Good Seeds	Per Cent Seeds Injured Missing	Pods Free of Insects or Injury	Pods With Holes	No. *Apion segnipes* Found	No. *Acanthoscelides obsoletus* Found	No. *Ulophora tephrosiella* Found	No. Parasites Found
Ingram, Va. 8/16/35 8/24/35	100	552	40.7	59.3	8	10	12 live 6 dead	0	60–0‡	2 *Eurytoma*
Keysville, Va. 8/16/35 8/26/35	100	659	70.4	29.6	39 (37 abnormal)	1	31 live 7 dead	1 live	3–9	1 *Eurytoma*
Kenbridge, Va. 8/16/35 8/26/35	100	601	23.9	76.1	2	12	19 live 11 dead	0	39–5	2 *Eurytoma*
Buckingham, Va. 8/17/35 8/27/35	100	559	48.3	51.7	21 (14 abnormal)	10	17 live 7 dead	2 live	55–2	1 *Eupelmus*
Pendleton, Va. 8/5/35 8/28/35	100	355	17.3	82.7	5	14	61 live 8 dead	4 live	23–2	2 *Eurytoma*
Largo, Md. 8/19/35 8/27/35	100	350	24.8	75.2	7	14	88 live 4 dead	5 live	11–2	2 *Eurytoma* 1 *Eupelmus*
Beltsville, Md. 9/17/35 9/18/35	94†	227	7.5	92.5	3	6 (All abnormal)	85 live 9 dead	0	1–0	0
Hearne, Tex. 9/5/35 9/10/35	100	721	61.9	38.1	0	0	0	0	98–0	0
Sandflat, Tex. 9/10/35 9/13/35 9/17/35	80†	516	48.6	51.4	0	4	0	1 dead	60–1	2 ♀ *Heterospilus* sp. 10 *Heterospilus* sp. Cocoons 5 *Heterospilus* sp. larvae

* Seeds that should have been present according to the appearance of the pod.
† Insect population calculated for 100 pods for comparison with other localities in fig. 2.
‡ First figure indicates the number of live larvae of *U. tephrosiella;* the second figure the number of pupae of this and other species. The sum of these in each case is used in fig. 2.

that flowers had been produced. In most localities, however, the pods were abundant. The cause of such absence of pods in some places is not at this time apparent, but the circumstances suggest that insect damage to the flower occurred. There was no opportunity at the time to investigate the matter, but careful examination of the plants during the blooming period to determine the causes of failure to produce seed is suggested.

Closed pods were preferred, because with such pods an accurate count of both insects and seeds can be obtained and a more critical examination of conditions within the pod is possible. The number of poorly developed or immature seeds can be easily determined by careful examination of the torula chambers (external swellings on the pod at each seed which are seen as depressions on the inside of the pod) and the funicles in the pod which are very clearly visible with the aid of a hand lens. By these means it is possible to determine the total number of seed that would have been present if there had been normal development and no insect damage. Many of the seeds fail to form, but such are included as "indications" together with those which have fully or partly developed (see table 1). As the open pods were in no case examined, the amount of insect damage that occurred in such pods was not determined. It is quite probable that pods in which there is little or no insect damage to the seed open in the normal way at maturity, whereas those in which the seed is largely destroyed do not open.

Preliminary examination of seed pods.—The seed pods collected August 5, 1935, at Pendleton, Va., were carefully opened with a scalpel, and all the insects found in various stages of development were submitted to the Bureau of Entomology and Plant Quarantine for determination. The following species were reported to be present:

COLEOPTERA.—*Apion segnipes* Say; Curculionidae, (det. by L. L. Buchanan). *Acanthoscelides obsoletus* Say; Bruchidae, (det. by H. S. Barber).

LEPIDOPTERA.—*Ulophora tephrosiella* Dyar; Pyralidae: Phycitinae, (det. by C. Heinrich). Undetermined species of Geometridae (det. by C. Heinrich).

HYMENOPTERA.—*Eurytoma tylodermatis* Ashm.; Eurytomidae, (det. by A. B. Gahan). *Eupelmus cyaniceps* var. *amicus* Girault; Eupelmidae, (det. by A. B. Gahan). *Heterospilus* sp.; Braconidae, (det. by C. F. W. Muesebeck).

Insects and condition of seeds found in pods.—With the labeled specimens as determined by the taxonomists as a guide, the adult insects were removed from the seed pods in the several lots collected and segregated. No attempt was made to segregate the immature forms of the different species, as this cannot be done accurately without previous study.

All lepidopterous and hymenopterous larvae subsequently secured were rechecked, the former by C. Heinrich and the latter by either A. B. Gahan or C. F. W. Muesebeck.

The two coleopterous larvae damaged the seed. The adults of *Apion* appeared much more abundant than those of *Acanthoscelides*. The *Apion* larvae always appear before those of *Acanthoscelides* and start feeding

when the seed is still in its earliest stages of development, while the latter do not enter the seed until the cotyledons are well developed and the seed coat has begun to assume its color pattern. According to J. C. Bridwell, who has had the *Apion* and *Acanthoscelides* under observation for several years, it must not be inferred from the small numbers of *A. obsoletus* found in the samples examined that this insect is not capable of extensive damage to the seed. If for some reason the population of the two early feeders *Apion* and *Ulophora* were greatly reduced, the damage capable of being done by *Acanthoscelides* would no doubt become more evident. *Apion* passes its entire immature stages between the valves of the pod, while *Acanthoscelides* is usually found pupating in the seed. When *Apion* has reached its adult stage no remnants of seed may remain between the valves or there may be a small fragment or rarely a little injured seed left. When *Acanthoscelides* emerges, the seed appears to be uninjured except for this insect's circular exit hole, but actually all but the seed coat has been consumed. One distinct characteristic damage of *Apion* is gall formation caused on the pods by the insect at its point of feeding. Neither *Apion* nor *Acanthoscelides* makes an exit hole through the pod but depends upon the ripe pod's opening to release them. Many of the pods opened contained one or more dead adults of *Apion segnipes*.

Of the two lepidopterous insects found, the one identified as belonging to the family Geomitridae occurred only once,[7] but the other, *Ulophora tephrosiella* Dyar, was found in all lots of pods examined.

Utophora larvae damage the entire contents of the pod, devouring the seeds and leaving only small pellets of brown excrement, fig. 1, C. The seed pods examined were fully ripe, and the larvae found were in their early stages of development. These insects probably pupate elsewhere after being released, since the dehiscence of the pod would seem to deprive them of a suitable place for pupation. The *larvae* range in color[8] from shades of reddish or pink, green or blue, to dull or pale yellow, but are seldom uniformly colored throughout all their abdominal segments.

The two hymenopterous parasites found, *Eurytoma tylodermatis* Ashm., and *Eupelmus cyaniceps* var. *amicus* Girault, differ greatly from each other, the former having deep, coarse depressions on the head and thorax while the latter is much more finely sculptured. The female of *Eurytoma* has the abdomen shorter and somewhat compressed while in female *Eupelmus* it is elongated and not compressed. The male *Eupelmus* can be easily distinguished from the male *Eurytoma* by its finer sculpturing and by the antennae, which in *Eupelmus* are threadlike or filiform while in *Eurytoma* they are saw-toothed and clothed with little hairs. According to Gahan, both these species are quite cosmopolitan in their taste, and it is difficult to determine without careful study what insect has served as host in cases where several possible hosts are found in the same seed pod.

The adult, cocoon and larval stages of an undescribed species of the

[7] Seen only once in preliminary examination of seeds.

[8] Notes by the U.S.D.A., Bureau of Entomology and Plant Quarantine are as follows: "Larvae indigo blue color and feeds on seeds of pods of *Cracca virginiana*. The pupal stage requires two weeks. Insect collected by H. W. Weiss, at Woodbine, N. J., Sept. 20, 1914."

genus *Heterospilus* were found only in the sample of seed pods collected at Sandflat, Tex. One dead larva of *Ulophora tephrosiella*, which had been killed by parasites, was found by C. F. W. Muesebeck on checking over the specimens, and according to him *Ulophora* is probably the host of this parasite. This can be definitely determined only by rearing the larvae to maturity. The larvae found were of a light blue-green color, with the initial anterior and posterior segments nearly white or colorless. The

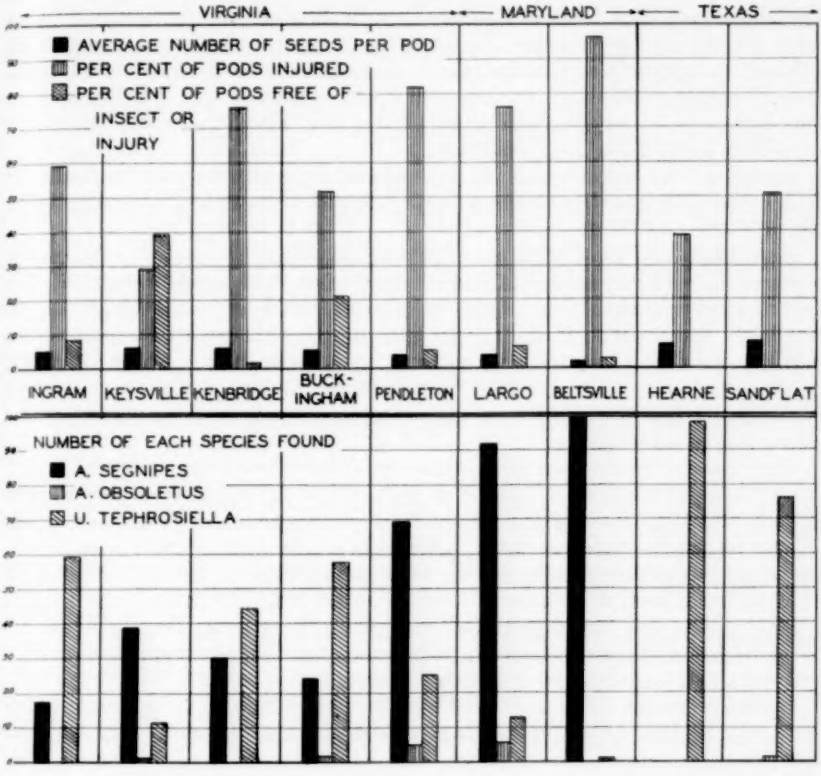

Fig. 2.—Comparative population of various species of insects and the condition of seeds found in pods of *Cracca virginiana* L.

six cocoons collected were white, about 4 mm. long, and of irregular form. Three adults emerged subsequently from these cocoons.

Examination of the seed pods revealed in some cases the following types of damage occurring in a single pod: (1) Partially or totally consumed seed: (2) partly consumed seed and seed coat surrounded by brown pellets of excrement; (3) seed seemingly intact but with its contents consumed and with a circular emergence hole.

In all the lots of seed pods examined few normal seeds were found. In the nine lots of closed and mature seed pods selected for examination

eight lots contained at least one pod with a hole, presumably an insect exit, the lots from Largo, Md., and Pendleton, Va., having the largest number, namely 14. While it is not certain what insect made these openings, it is probable that these are the exit holes of the larvae of the moth emerging to pupate elsewhere. The seed pods from Hearne, Tex., were longer than any of the others, contained the best developed seeds, and were the most difficult to open.

The Durham color test when applied to unconsumed portions of insect-damaged seed from Sandflat, Tex., indicated the presence of rotenone and related substances. Apparently these substances in the amount present or under the circumstances are not toxic to the insects in question. Negative results were obtained when the same test was applied to the larvae of *U. tephrosiella* taken from the pods, the seed fragments of which gave a positive reaction.

Result of the examination of the several lots of seed pods is found in found in table 1, with certain salient features represented graphically in fig. 2.

Summary and conclusions.—Investigations of the native *Cracca virginiana* L. with regard to its possibilities as an insecticide developed the fact that the propagation of this plant from seed on a large scale would probably meet with difficulties on account of widespread damage to its seed by insects. The probable importance of this in case the cultivation of the plant were to be generally undertaken prompted the investigation reported here of the identity of the injurious insects and the extent of the damage caused by them.

Seed pods secured from nine localities from three states showed heavy insect infestations. In 874 pods examined only 1669 normal seeds were found, although theoretically over 4600 seeds should have been present. There is much evidence that this condition is due primarily to insect damage, but other circumstances which from time to time may result in the failure of seed development are no doubt responsible to some extent.

The *Apion* was found in all lots excepting those from Texas, the Beltsville, Md., lot showing the highest percentage of infestation. Of the three insects, *Apion* causes the greatest damage.

Acanthoscelides (*Bruchus*) *obsoletus* Say occurred in very small numbers, the highest being in the Largo, Md., lot and none occurring in the lots from Ingram and Kenbridge, Va., Beltsville, Md., and Hearne, Tex. This insect, however, is also capable of doing a great deal of damage to the seed.

Larvae of *Ulophora tephrosiella* Dyar were found in all lots examined, the one from Hearne, Tex., having the highest, namely 98, and Beltsville only one. More than one *Ulophora* larva was seldom found in a single seed pod. However, in the lot from Buckingham, Va., two were found in one instance, and in the lot from Hearne a single larva was found in 94 of the 100 pods examined.

The number of parasites found in all lots examined was very low, with none occurring in the Hearne and Beltsville lots. The undescribed species of the genus *Heterospilus* was found only in the Sandflat, Tex., lot. Two species of parasites were found in the same pod in only one instance and

that occurred in the lot from Largo. Due to the fact that several species of insects are found in the same pod accompanied occasionally by more than one species of parasites, it is difficult to determine without further careful studies which of such insects are the host of the parasites present.

Information thus far obtained shows that the larvae of *Apion* and *Ulophora* do much damage to the seeds of the *Cracca virginiana* L., but that little injury is caused by *Acanthoscelides*.

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Scientific Notes

Comparison of Tetrahydronaphthalene and Ethylene Dichloride–Carbon Tetrachloride Mixture as Fumigants Against Clothes Moth Larvae.—Much excellent work has been done on the relative toxicity of insect fumigants under ideal conditions, but very little on their relative effectiveness under conditions approaching those of actual use. The purpose of the investigations reported herein is to compare with a standard household fumigant, under such conditions, a material that shows promise as a household fumigant against fabric pests. The fumigants were, respectively, a commercial grade of tetrahydronaphthalene and a mixture of 75 per cent by volume of ethylene dichloride and 25 per cent carbon tetrachloride. They were tested against larvae of the webbing clothes moth, *Tineola biselliella* Hummel.

Procedure.—The two fumigants were used in equal volumes under identical conditions, and the tests were carried out simultaneously in specially constructed cabinets made of wallboard, with an external frame of wood. The cabinets were approximately 71 cubic feet (about 2000 liters) in capacity and were as nearly alike as ordinary carpenter work would permit.

The larvae were reared on sterilized raw sheeps' wool to which had been added a small quantity of devitalized powdered brewer's yeast.[2] They were kept at a constant temperature of 25° C (77° F) and a relative humidity of 40 to 50 per cent.

Three hundred larvae were required for a test. A much larger number than this were separated from the wool by placing a thin layer of wool over wire screen with an electric bulb immediately above, the larvae dropping into a receptacle below. Larvae for a test were always taken from the same culture, and only healthy appearing, active larvae, one-half to two-thirds grown, were selected. The larvae were placed in cages, previously described,[3] and allowed 48 hours to become established on the squares of cloth with which each cage was provided. Powdered brewer's yeast was added to the cloth in each cage.

Three fumigation cabinets, placed side by side under the same external conditions, were used in making a test, one cabinet for each fumigant and one as a check. Four cages containing 25 larvae each were placed at the same height and in the same relative position in each cabinet. As the temperature of the room in which the fumigation cabinets were

[1] **Colman, W.** 1934. Hydrogenated naphthalene against clothes moths. Jour. Econ. Ent. **27**(4):860. Aug.
[2] **Colman, W.** 1932. Effect of yeast on clothes moth larvae. Jour. Econ. Ent. **25**(6):1242. Dec.
[3] **Colman, W.** 1932. A cage for clothes moth larvae. Jour. Econ. Ent. **25**(6):1108. Dec.

placed was below that suitable for effective fumigation, temperatures inside the cabinets were maintained by electric space heaters and thermostats, which were set at 22.5°C (72.5° F).

In six of the eight tests there was no forced circulation of the air, but in the other two a 16-inch electric fan was operated in each cabinet in circuit with the electric heaters.

In the tests without forced air circulation there was considerable temperature variation within the cabinets, but it is believed that the variation in each cabinet was approximately the same, since the heating equipment was exactly the same and arranged in the same way.

Fumigation tests with tetrahydronaphthalene and ethylene dichloride–carbon tetrachloride mixture against larvae of *Tineola biselliella*.

	No Forced Circulation of Air						Forced Circulation of Air		
Test	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
Hours of Exposure of Larvae to Fumigant	72	72	72	72	48	24	24		24
Total No. Larvae Used	300	300	300	150	300	300	300		300
Cc. of Fumigant Used	200	100	50	25	100	100	100	50	25*
Per Cent of Larvae Killed by Fumigant									
Tetrahydronaphthalene									
Cage 1	100	100	92	76	100	72	100	72	80
Cage 2	100	100	100	68	100	64	100	92	52
Cage 3	100	100	100	76	88	64	100	88	72
Cage 4	100	100	96	80	96	68	100	76	64
Average	*100*	*100*	*97*	*75*	*96*	*67*	*100*	*82*	*67*
Ethylene dichloride–carbon tetrachloride									
Cage 1	100	40	4		72	20	16		
Cage 2	100	64	8		28	32	4		
Cage 3	100	72	0		48	28	16		
Cage 4	100	68	8		40	28	8		
Average	*100*	*61*	*5*		*47*	*27*	*11*		
Per Cent of Larvae Dead in Check Cages									
Cage 1	32	20	0	8	28	24	8		12
Cage 2	20	24	8	4	32	44	20		0
Cage 3	16	16	4		36	28	16		4
Cage 4	16	24	12		36	32	4		4
Average	*21*	*21*	*6*	*6*	*33*	*32*	*12*		*5*

* Two dosages (50—25 cc.) of tetrahydronaphthalene and the corresponding check run simultaneously.

Tetrahydronaphthalene is so slowly volatile that it is impractical to apply it by exposure in pans, as is frequently done with the ethylene dichloride–carbon tetrachloride mixture. Complete volatilization of the fumigants would require special equipment, the use of which would not be consistent with the basic idea of this work. Therefore, the fumigants were merely absorbed in about 3 square yards of burlap, which was hung near the top of the cabinet.

After the fumigation the larvae were transferred to the check cabinet for one week before mortality counts were made. While this delay increases mortality in the checks, the author believes that greater accuracy is attained thereby.

Results.—Results of the tests are given in the accompanying table.

The results show that, under the conditions of the tests, tetrahydronaphthalene is more effective than the ethylene dichloride–carbon tetrachloride mixture. While the results are indicative of the comparative effectiveness of the two fumigants under practical conditions, it should be emphasized that the amounts of the fumigants used are in no sense practical recommendations. Practical conditions vary widely, and many factors, such as leakage and the presence of absorptive materials, influence the amount of a fumigant that may be required for a given space.

Summary.—Tetrahydronaphthalene was compared with a mixture of 75 per cent by volume of ethylene dichloride and 25 per cent carbon tetrachloride as a fumigant against larvae of the webbing clothes moth, *Tineola biselliella* Hummel. Simultaneous tests with equal amounts of fumigants in twin fumigation cabinets under identical conditions, which approached those of actual use, showed that tetrahydronaphthalene is the more effective of the two fumigants.

Wallace Colman, *U.S D.A., Bureau of Entomology and Plant Quarantine*, 3-6-36

Efficiency of *Trichogramma minutum* Riley in Relation to Population Density of its Host.—Among recent observations of *Trichogramma minutum* Riley, three examples of high efficiency of this egg parasite have been noted. Descriptions of the circumstances of these examples follow, together with an attempt to set forth the probable conditions under which the parasite attains efficiency.

At Savannah, Ga., in 1933, a half acre of corn was observed that had been planted very early. By May 15 unusually large numbers of eggs were being deposited on this corn by moths of *Heliothis obsoleta* Fab. At this time the corn in this field was the most advanced in the vicinity, and moths seemed to be attracted to it from some distance. Eggs were laid on all parts of the plants, especially on the upper surfaces of leaves, before silks appeared. By May 25, when most of the plants bore ears, at least a hundred eggs of *H. obsoleta* had been deposited per plant, and most of these had been parasitized by *Trichogramma*, a much larger percentage being attacked than is usually the case with eggs of *H. obsoleta* on corn. Later in the year, as corn became abundant, the population of *H. obsoleta* became diffused through the cornfields, and eggs were laid at the rate of only a few per plant. Then parasitization by *T. minutum* had become reduced to an unimportant level, as is usually the case.

Late in the summer and in the fall of 1933, in Washington county, Ga., heavy infestations of *Heliothis obsoleta* and *Anticarsia gemmatilis* Hbn. occurred in fields of soy beans. By September 15 an enormous population of moths of *H. obsoleta* occurred in a 100-acre field which was as yet little injured by caterpillars. By September 23 eggs of *H. obsoleta* were being deposited in large numbers on bean plants, as many as three to a single blossom and six to a single leaf being recorded. By September 28 parasitization of these eggs by *T. minutum* was at the rate of 91.8 per cent, and, notwithstanding the number of eggs that had been laid on the bean plants, few eggs hatched, and the surviving larvae were too few to do serious damage to the plants.

During 1934, again in Washington county, Ga., *Anticarsia gemmatilis* appeared in soybean fields during August and September, but failed to build up large populations or do serious damage to the plants, owing, apparently, to unfavorable weather. During this period, few of the eggs were parasitized by *T. minutum*. By the middle of October, however, in the late-planted beans, *Anticarsia* had become abundant, and defoliation of the plants occurred in parts of the fields. During the last two weeks of October many moths were in flight, and eggs were deposited in large numbers, on an average several per bean leaf. At this time *Trichogramma* appeared and by October 25 had parasitized most of the *Anticarsia* eggs.

Observations of the habits of *T. minutum* seem to show that the adults find host eggs only by exploration, and that host eggs are recognized only when the parasite adults come upon them. Thus, beginning at a given point of time with equal parasite populations of similar duration of life, if host eggs are scarce, exploration by the parasites may bring them in contact with few of them and, consequently, they may themselves deposit few eggs before dying. In such circumstances the parasite population may not increase—in fact, it may actually decrease. On the other hand, when host eggs are very abundant, the parasites may find them much more readily by exploration, they may themselves lay eggs in many more host eggs before dying, and, as a result, the parasite population increases rapidly.

It is thought that this is the explanation of the high efficiency of *T. minutum* in the examples given. Although the parasite is usually found attacking eggs of the hosts mentioned, when these eggs are relatively few in the field parasitization is usually inconsequential as a limiting factor. Only when the population of the hosts becomes unusually great is the parasite found occurring in sufficient numbers to effect control. The conclusion is drawn therefore that, other factors being equal, a correlation exists between the efficiency of the parasite and the abundance of its hosts, and that it is in instances where the hosts are unusually abundant that the parasite is able to become effective as an important limiting factor in the control of its host.

GEORGE W. BARBER, *U.S.D.A., Bureau of Entomology and Plant Quarantine.* 4-29-36

Nitrogen Trichloride as a Fumigant.—Nitrogen trichloride is used extensively in certain industries, particularly in maturing flour, under the trade name of *Agene*. More recently this gas has been found to kill spores of certain decay organisms including the common green and blue molds *Penicillium digitatum* and *P. italicum*. Some orange packing-houses in California are now treating fruit with nitrogen trichloride under the trade

name *Decco* as a decay retardent. The chemistry and use of this material as a fungicide has been covered by Klotz [Hilg. 10(2)].

In connection with the treatment of certain export fruit to eliminate living bean thrips, *Hercothrips fasciatus* Perg., from citrus, it was found desirable to determine the effect of nitrogen trichloride on the thrips. In commercial *Decco* treatment of oranges, a concentration of about .3 mg. per liter (.025 per cent concentration by weight) of air is maintained by constantly introducing the gas for exposures for as long as six hours. This dosage was found to have no particular lethal effect, although it caused considerable irritation and activity of the thrips. Limited observations indicated that a concentration of about 1.4 mg. per liter of air, with an exposure for at least four hours, was necessary for 100 per cent kill. The following observations were made:

Test	Nitrogen Trichloride *mg. per liter of air*	Hours Exposure	Bean Thrips Dead	Alive
1	.77	2	41	31
2	1.6–2.7	2	235	1
3	1.4	4	221	0
Check	No treatment		14	71

In the following tests the gas concentration was maintained at the indicated strength for the length of the exposure. At the end of the exposure no more gas was introduced but the fumatorium was not opened for an additional 12 hours.

Test	Nitrogen Trichloride *mg. per liter of air*	Hours Exposure	Bean Thrips Dead	Alive
4	.77	6	199	0
5	.77	6	147	1
6	1.1	6	127	0
7	1.1	6	214	0
8	1.4	6	126	0
9	1.6	6	73	0
10	1.6–2.7	2	183	0

The above observations were made, using navel oranges, during the month of December, when bean thrips may be found hibernating in the naval ends. Some winter mortality normally occurs, which accounts for the few dead in the check.

Dosages of nitrogen trichloride strong enough to give a complete kill of bean thrips have been above the tolerance of oranges to injury.

R. S. Woglum and H. C. Lewis, *California Fruit Growers Exchange*. 4-6-36

New Nymphal-adult Parasite of White Apple Leafhopper.—Study of the natural enemies of the white apple leafhopper, *Typhlocyba pomaria* McAtee, has been in progress in eastern New York since 1933. In many orchards of the Hudson valley fruit district a recently described bethylid, *Aphelopus typhlocybae* Muesebeck (Proc. Wash. Ent. Soc., Nov. 1935) has been of second importance only to the egg parasite *Anagrus armatus* Ashmead var. *nigriventris* Girault. The nymphal-adult parasite corresponds to the host in having two generations annually. Emergence of adults from cocoons in the soil closely parallels the hatching of leafhopper nymphs in the region of Poughkeepsie, N. Y., and slightly precedes the hatching of nymphs of the second brood in the Champlain valley. Adults are frequently very abundant in late May and again in August. They are extremely active and move rapidly over the foliage in search of hopper nymphs.

The host is attacked in the early instars. *A. typhlocybae* oviposits occasionally in the side of the host thorax but more frequently in the anterior abdominal segments. The first external sign of parasitism becomes visible in from one to three weeks after the hoppers reach the adult stage. At this time the larva is enclosed in a small pouch which enlarges rapidly as the parasite grows. No more than one larva reaches maturity on a parasitized hopper, though as many as five immature larvae have been observed on a single host. Parasite larvae mature in two to four weeks after the first appearance of larval pouches on the sides of the hosts and in three to seven weeks after the host nymph reaches the adult stage. Parasitized hoppers bearing fully developed larvae are most abundant on the low hanging branches of apple trees. The parasite "larval drop" normally reaches peaks during the first week of July and the first half of October, according to frequent examinations of

sheets stretched beneath infested trees. Any determination of the degree of parasitism should be made prior to the beginning of this parasite larval drop. The bodies of thousands of hoppers, killed by *Aphelopus*, have been found clinging to foliage for several weeks after they have been deserted by the parasites. Upon leaving the host, the larvae drop to the ground and spin cocoons just beneath the soil surface.

Orchard	Description	Year	Percentage of Parasitism	
			First-brood Hosts	Second-brood Hosts
1	Undisturbed sod	1933		42
		1934	74	39
		1935	65	32
2A	Undisturbed sod	1935		59
3	Undisturbed sod	1934	41	30
9	Undisturbed sod	1935		51
4	Cultivated at random	1934	1	8
		1935		10
5	Cultivated at random	1934	2	9
		1935	9	13
6	Cultivated at random	1934	21	20
8	Cultivated at random	1935	4	12
1A	Partly cultivated and mulched with straw	1934	48	30
		1935	50	34
2	Cultivated prior to 1933	1933		19
		1934	27	37
		1935		20
7	Cultivated only in June	1935	58	78

The time of larval maturity and the conditions favoring the establishment of cocoons in the soil are regarded as the critical points in the life cycle of this species. A high mortality of larvae occurs during early July when the larvae drop on unshaded soil beneath trees and are exposed to direct sunlight for a short time. Within an orchard, parasitism is generally highest on trees with many low hanging branches. It is higher in sod orchards than in cultivated orchards except where cultivation is practised only during periods when parasites are feeding on the hosts. These periods extend through June and September.

Typhlocyba pomaria, the white apple leafhopper, is the only host known at present. An effort has been made recently by entomologists of the Cawthron Institute, in which the writer has cooperated, to establish *A. typhlocybae* as a parasite on the yellow apple leafhopper, *T. australis* Frogg. (*xanthippe*) in New Zealand.

The degree of parasitism observed just prior to the parasite larval drop is summarized in the accompanying table.

Harold M. Steiner, *New York Agricultural Experiment Station*. 4-6-36

Enemies of the Mexican Mealybug, *Phenacoccus gossypii* (T. & Ckll.)—While carrying on some control experiments on the Mexican mealybug during the summer of 1935, a number of predators and a parasite were observed. Of these the parasite, *Leptomastidea abnormis* Girault, was by far the most numerous. In 1932 Dozier reported the appearance of this species in Illinois, where it was attacking the same host, but this is the first time to the writer's knowledge that it has been reported from New York state. In the late summer and early fall the parasite's activities in the Cornell University insectary very markedly reduced the mealybug population on infested coleus plants. On a number of occasions the larvae of the lacewing *Chrysopa oculata* Say were observed feeding on mealybugs. In one instance a nearly mature larva fed on nine nymphs and adults during the course of an hour. A syrphid, *Toxomerus marginata* Macquart, was reared from larvae taken from the same plants. Frequently after having been fed on and discarded by the syrphid larvae, mealybugs were seen to walk drunkenly away but none observed survived for a period longer than two hours.

W. E. Heming, *Cornell University*. 4-3-36

Insects Infesting Cotton Seed.—Four species of live insects have recently been found in stored cotton seed in Georgia. These were *Carpophilus dimidiatus* (Fab.), *Laemophloeus minutus* Oliv., *Tribolium ferrugineum* (Fab.), and *Pyroderces rileyi* (Wlsm.). The first species was found in the larval and adult stages, the second and third in the adult, and *Pyroderces* in larval stages only.

Pyroderces rileyi, which is known as the pink corn worm or pink scavenger worm, and *Tribolium* occurred in the screenings from cotton seed of the 1935 crop but none of the seed was found to be injured.

The three beetles, *Carpophilus dimidiatus*, known as the corn sap beetle, *Laemophloeus* and *Tribolium*, were found in a lot of seed which had been in storage at least one, and possibly two years. Of these seed 1.9 per cent had been infested by some insect and a few contained adults and larvae of *Carpophilus*. Injured seeds were disclosed by a spot of yellow powder in the lint at the entrance hole and usually the whole kernel was reduced to frass of a bright yellow color. The kernels of uninfested seeds were white with many red bodies scattered throughout. Whether the *Carpophilus* beetles were the first to attack the seed cannot be stated, but this insect was the most common of the several species found.

THEO. L. BISSELL, *Georgia Experiment Station*. 3-18-36

NEWELL ENTOMOLOGICAL SOCIETY

CLOSING A FLORIDA state-wide entomological conference, held in Gainesville February 28, entomological students and faculty members of the University of Florida attended an installation banquet for the Newell Entomological Society.

Named in honor of Dr. Wilmon Newell, the Society is a student organization dedicated to the dissemination of entomological knowledge in general and that of applied entomology in particular. Dr. Newell is Dean of the College of Agriculture, Director of the Florida experiment station, and Plant Commissioner of the Florida State Plant Board. Continued advance of all phases of entomology, depending on layman acceptance and support of control work, will be encouraged by press and radio publicity as well as talks at educational institutions. First president is W. P. Hunter, graduate instructor in the Department of Economic Entomology and Plant Pathology.

One hundred persons attended both sessions of the state conference. John J. Tigert, President of the University of Florida, gave the address of welcome. Included on the morning program devoted to medical and veterinary entomology were E. W. Laake, W. V. King, W. G. Bruce and G. H. Bradley of the Bureau of Entomology and Plant Quarantine, and Mark F. Boyd of the Rockefeller Foundation. The afternoon session for discussion of varied state problems was addressed by E. N. Berger and R. E. Foster of the Florida State Plant Board; R. V. Lobdell, W. L. Thompson, J. R. Watson and John W. Wilson, Florida Experiment Station; W. W. Yothers of Yothers' Citrus Service; and Ralph L. Miller of the Florida Agricultural Supply Company. The writer was chairman of the conference.

Guest speaker in the installation banquet was Dr. Herbert Osborn, Professor Emeritus of Ohio State University. H. Harold Hume, Assistant Director of the Florida experiment station, was toastmaster, and other speakers were H. T. Fernald, Professor Emeritus of Massachusetts Agricultural College; Towns R. Leigh, Vice President of the University of Florida; P. H. Rolfs, former Dean of the College of Agriculture, University of Florida; Herbert Spencer and C. F. Stahl of the Bureau of Entomology and Plant Quarantine.

JOHN T. CREIGHTON, *University of Florida*

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